NDIA

ARMY SCIENCE & TECHNOLOGY
SYMPOSIUM AND SHOWCASE

EMPOWERING A SOLDIER'S SUCCESS

August 21 – 23, 2018

Walter E. Washington Convention Center

Washington, DC

NDIA.org/Army-Science

TABLE OF CONTENTS

NDIA

WHO WE ARE

The National Defense Industrial Association is the trusted leader in defense and national security associations. As a 501(c)(3) corporate and individual membership association, NDIA engages thoughtful and innovative leaders to exchange ideas, information, and capabilities that lead to the development of the best policies, practices, products, and technologies to ensure the safety and security of our nation. NDIA's membership embodies the full spectrum of corporate, government, academic, and individual stakeholders who form a vigorous, responsive, and collaborative community in support of defense and national security. For more information, visit **NDIA.org**

SCHEDULE AT A GLANCE

TUESDAY, AUGUST 21

Registration Open
7:00 am - 5:30 pm

General Session
8:00 - 9:30 am

Grand Opening of the Science & Technology Showcase & Poster Review
9:30 am - 5:30 pm

General Session
10:00 - 11:30 am

Lunch
11:15 am - 1:00 pm

Concurrent Sessions
1:00 - 2:00 pm

Concurrent Sessions
2:30 - 3:30 pm

Welcome Networking Reception and Poster Review
3:30 - 5:30 pm

WEDNESDAY, AUGUST 22

Registration Open
7:00 am - 6:30 pm

General Session
8:00 - 9:30 am

Grand Opening of the Science & Technology Showcase and Poster Review
9:30 am - 6:30 pm

General Session
10:00 - 11:30 am

Lunch
12:00 am - 1:00 pm

Concurrent Sessions
1:00 - 3:00 pm

Concurrent Sessions
3:30 - 4:30 pm

Networking Reception and Poster Review
4:30 - 6:30 pm

THURSDAY, AUGUST 23

Registration Open
7:00 - 11:30 am

Concurrent Sessions
8:00 - 10:00 am

Concurrent Sessions
10:30 - 11:30 am

Symposium Concludes
11:30 am

EVENT INFORMATION

LOCATION

Walter E. Washington Convention Center
801 Mt. Vernon Place NW
Washington, DC 20001

EVENT WEBSITE

NDIA.org/Army-Science

EVENT THEME

Empowering a Soldier's Success

ATTIRE

Civilian: Business
Military: Uniform of the day | For military speakers, we recommend Service dress.

SURVEY AND PARTICIPANT LIST

You'll receive via email a survey and list of attendees (name and organization) after the conference. Please complete the survey, which helps make our event even more successful in the future.

EVENT CONTACT

GENERAL EVENT

Britt Sullivan, CMP
Associate Director
Meetings and Special Projects
(703) 298-1514
bsullivan@ndia.org

AGENDA

Daniel Lung
Program Coordinator
Program Development
(703) 247-9476
dlung@ndia.org

EXHIBITS & SPONSORSHIP

Allison Carpenter, CEM, CMP
Director
Exhibits and Sponsorship
(703) 247-2573
ahcarpenter@ndia.org

REGISTRATION

Renata Casiel
Meeting Planner
(703) 247-2561
rcasiel@ndia.org

SPEAKER GIFTS

In lieu of speaker gifts, a donation will be made to the Fisher House Foundation.

HARASSMENT STATEMENT

NDIA is committed to providing a professional environment free from physical, psychological, and verbal harassment. NDIA will not tolerate harassment of any kind, including but not limited to harassment based on ethnicity, religion, disability, physical appearance, gender, or sexual orientation. This policy applies to all participants and attendees at NDIA conferences, meetings and events. Harassment includes offensive gestures and verbal comments, deliberate intimidation, stalking, following, inappropriate photography and recording, sustained disruption of talks or other events, inappropriate physical contact, and unwelcome attention. Participants requested to cease harassing behavior are expected to comply immediately, and failure will serve as grounds for revoking access to the NDIA event.

AGENDA

TUESDAY, AUGUST 21

7:00 AM – 5:30 PM **REGISTRATION OPEN**
EXHIBIT HALL C

7:00 – 8:00 AM **CONTINENTAL BREAKFAST**
PREFUNCTION OF ROOM 146

8:00 – 8:15 AM **WELCOME REMARKS**
ROOM 146
Gen Herbert "Hawk" Carlisle, USAF (Ret)
President and CEO, NDIA

8:15 – 9:00 AM **KEYNOTE SPEAKER**
ROOM 146
GEN James C. McConville, USA
Vice Chief of Staff

9:30 AM **GRAND OPENING OF THE SCIENCE & TECHNOLOGY SHOWCASE AND POSTER REVIEW IN EXHIBIT HALL**
EXHIBIT HALL C

9:15 – 10:00 AM **GUEST SPEAKER**
ROOM 146
Dr. Bruce D. Jette
Assistant Secretary of the Army (Acquisition, Logistics and Technology)

10:00 – 10:30 AM **NETWORKING BREAK IN EXHIBIT HALL** Sponsored by PAE ISR
EXHIBIT HALL C

10:30– 11:15 AM **GUEST SPEAKER**
ROOM 146
LTG Thomas Spoehr, USA (Ret)
Director, Center for National Defense, The Heritage Foundation

11:15 AM – 1:00 PM **LUNCH ON YOUR OWN**

CONCURRENT TECHNICAL SESSIONS

1:00 – 2:00 PM

C3/C4ISR

ROOM 152 A/B

Network/C3I Army Modernization Priority

Mr. Seth Spoenlein

Deputy Director, Space and Terrestrial Communications Directorate, Army Communications-Electronics Research, Development and Engineering Center

Embedding Simulation into Mission Command Systems

Dr. John R. Surdu

Senior Scientist, Cole Engineering Systems, Inc.

Use of RF Spectrum Monitoring Assets for 3D Geolocation and Drone Detection

Mickey Patterson

Senior Account Executive, CRFS

1:00 – 2:00 PM

INTEGRATED FIRES

ROOM 151 A/B

Army Science and Technology to Support Long Range Precision Fires Modernization

Michael C. George

Army Research, Development, and Engineering Command

Digital Radar Technology for Air and Missile Defense

Dr. Gregory Mitchell

Army Research Laboratory

Integrating Fires for Air and Missile Defense C2: The Human Dimension

Rob Jassey

Program Manager, Missile Defense and Protective Systems Division, Northrop Grumman

1:00 – 2:00 PM

PANEL: DISRUPTIVE TECHNOLOGIES

ROOM 150 A/B

Blaise Zandoli

Army Applications Lab, Army Futures Command

Moderator

Dr. Paul Baker

Atomic and Molecular Program Manager, Army Research Laboratory

Dr. Henry Kapteyn

JILA, University of Colorado, and KMLabs

Dr. Jerrold Prothero

Co-founder and CEO

Astrapi Corp.

2:00 – 2:30 PM

NETWORKING BREAK IN EXHIBIT HALL

Sponsored by PAE ISR

EXHIBIT HALL C

CONCURRENT TECHNICAL SESSIONS

2:30 – 3:30 PM

PANEL: HUMAN APTITUDE ASSESSMENTS

ROOM 152 A/B

Dr. Kara Orvis
Vice President, Research and Development Group, Aptima, Inc.
Moderator

Dr. Randy J. Brou
Research Psychologist
Army Research Institute

Dr. William S. Weyhrauch
Research Psychologist
Army Research Institute

Dr. Alexander Wind
Research Psychologist
Army Research Institute

2:30 – 3:30 PM

PANEL: MACHINE REASONING FOR DECISION SUPPORT

ROOM 151 A/B

Syeed Mansur
CEO, DeepCortex
Moderator

Dr. Lance Kaplan
Team Leader
Army Research Laboratory

Dr. Charles Kim
Professor, Howard University

Dr. Nick Vlahopoulos
Professor, University of Michigan

2:30 – 3:30 PM

EXPEDITIONARY OPERATIONS

ROOM 150 A/B

Resilient Communications with Hybrid Adaptive Networking
Craig Miller
Vice President and Chief Technical Officer, Viasat, Inc.

Deep Learning Application for Radio Frequency Data
Adam Thompson
Senior Solutions Architect, NVIDIA

Large Virtual Aperture Hyper-spectral NANO-SAT Formations for Operationally Responsive Space-based Identification and Tracking of Fuel Vapors, Lethal Gasses, and Other Hyperspectral Applications
Arnold Kravitz
President, Innovim Defense Services

Energy Efficient “Shelter in Shelter” Concept for Large Expeditionary Structures Application
Reza Salavani
Energy Program Manager, Air Force Civil Engineer Center

3:30 – 5:30 PM

WELCOME NETWORKING RECEPTION AND POSTER REVIEW IN EXHIBIT HALL

EXHIBIT HALL C

WEDNESDAY, AUGUST 22

7:00 AM – 6:30 PM

REGISTRATION OPEN

EXHIBIT HALL C

7:00 – 8:00 AM

NETWORKING CONTINENTAL BREAKFAST

PREFUNCTION OF ROOM 146

8:00 – 8:15 AM

ADMINISTRATIVE REMARKS

ROOM 146

Capt Frank Michael, USN (Ret)
Senior Vice President of Program Development, NDIA

8:15 – 9:00 AM

KEYNOTE SPEAKER

ROOM 146

Mary Miller
Performing the Duties of Assistant Secretary of Defense for Research and Engineering

9:00 – 9:30 AM

GUEST SPEAKER

ROOM 146

Dr. Thomas Russell
Deputy Assistant Secretary of the Army (Research and Technology)

9:30 AM

OPENING OF THE SCIENCE & TECHNOLOGY SHOWCASE AND POSTER REVIEW IN EXHIBIT HALL

EXHIBIT HALL C

9:30 – 10:00 AM

NETWORKING BREAK IN EXHIBIT HALL

Sponsored by PAE ISR

EXHIBIT HALL C

10:15 – 11:00 AM

GUEST SPEAKER

ROOM 146

MG Bill Hix, USA (Ret)
Founder and Managing Partner, Next Horizons Partners

11:00 – 12:00 AM

PANEL: SCIENCE TO APPLICATION, OVERCOMING THE TECHNOLOGY VALLEY OF DEATH

Dr. Thomas Russell
Deputy Assistant Secretary of the Army (Research & Technology)

John S. Willison
Deputy to the Commanding General of Army Research, Development, and Engineering Command

Dr. David E. Walker
Director of Technology
Office of Naval Research

Thomas Lockhart
Director of Plans and Programs,
Air Force Research Laboratory

Dr. Thomas Karako
Senior Fellow, Director of the Missile Defense Program,
Center for Strategic and International Studies

12:00 – 1:00 PM **LUNCH ON YOUR OWN**

CONCURRENT TECHNICAL SESSIONS

1:00 – 2:00 PM

PANEL: IMMERSIVE TECHNOLOGIES

ROOM 152 A/B

RADM James A. Robb, USN (Ret)
President, National Training and Simulation Association
Moderator

Dave Fluegeman
Vice President of Simulation, Barco

Dr. David Darkow
Army Research, Development, and Engineering Command

Dr. W. Geoffrey Wright
Associate Professor
Temple University

1:00 – 2:00 PM

MATERIALS SCIENCE

ROOM 151 A/B

Friction Stir Welded Aluminum Hull Structure Material Fatigue Analysis
Victor Burguess
Army Research, Development, and Engineering Command

Development of Flexible Wrinkle-free Optical Stress Sensor for Studying Cell Substrate Interactions
Dr. Jian Sheng
Associate Professor, Texas A&M University - Corpus Christi

Enhancing Warfighter Performance with Non-Invasive Neurostimulation Enabled by Dry Skin Electrodes
Dr. Amy M. Heintz
Research Leader, Battelle

Phase Change Material Filled Graphite for Electronics Cooling in Transient Environments
Dr. James W. Klett
Senior Research Staff Member, Oak Ridge National Laboratory

1:00 – 2:00 PM

OPERATIONAL/EXPEDITIONARY ENERGY

ROOM 150 A/B

Advances in Li/CFx Non-rechargeable Batteries for Portable Electronic Systems
Julianne Douglas
Energy Harvesting Technology Lead, Army Communications-Electronics Research, Development and Engineering Center

Soldier-Borne Power Generation in Tier 1 Environments
Noel Soto
Army Research, Development, and Engineering Command

Photovoltaic/Thermal (PV/T) Energy Addition to Expeditionary Buildings
Michael Tomac
Process and Design Engineer, South Dakota School of Mines and Technology

Active Cooling Thermally Induced Vapor-Polymerization Effect (ACTIVE)
Dr. Gong Zhou
Senior Chemical Engineer, SMART Energy Group, Applied Research Associates, Inc.

CONCURRENT TECHNICAL SESSIONS

2:00 – 3:00 PM

HUMAN SYSTEMS INTEGRATION

ROOM 152 A/B

Preliminary Characterization of Head-Supported Mass Exposure in a Simulated Dismounted Operating Environment

Dr. Bethany L. Shivers
Research Kinesiologist, Army Aeromedical Research Laboratory

Graphene Electronic Tattoos for Imperceptible Human Monitoring and Human-System Interfaces

Dr. Deji Akinwande
Professor, University of Texas – Austin

Tactical Augmented Reality, Precisely Where You Need It: Bringing Registered AR to the Field

Eric M. Jones
Human Systems Architecture, Draper

2:00 – 3:00 PM

PANEL: STEM/EDUCATIONAL OUTREACH

ROOM 151 A/B

David Burns
Director, STEM Innovation Networks, Battelle
Moderator

Jacey Wilkins Cavanagh
National Coordinator, MakerMinded

Dr. Victor M. Nakano
Executive Program Director, Johns Hopkins University

Evelyn Villanueva
Research Geologist, Army Corps of Engineers, Engineer Research and Development Center

Justin Wang
Student, Chantilly High School

2:00 – 3:00 PM

DIRECTED ENERGY

ROOM 150 A/B

A Compact Modular High-Power Microwave Gun

Dr. James Tatoian
Chairman and CEO, Eureka Aerospace Inc.

Lasers for DEW Based on Fully Crystalline Fibers

Dr. Mark Dubinskiy
Team Lead, Advanced Solid State Lasers, Army Research Laboratory

New Process for Efficient Laser Pumping for IRCM: Three-for-One Cross-Relaxation

Dr. Larry Merkle
Scientist and Engineer, General Technical Services

3:00 – 3:30 PM

NETWORKING BREAK IN EXHIBIT HALL

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EXHIBIT HALL C

CONCURRENT TECHNICAL SESSIONS

3:30 – 4:30 PM

PANEL: MANNED-UNMANNED TEAMING

ROOM 152 A/B

Matt Whalley
Army Aviation and Missile Research, Development, and Engineering Center
Moderator

Jeffery Ernat
Team Leader for Autonomy Teaming, Army Tank Automotive Research and Development Engineering Center

Dr. Ozlem Kilic
Professor, The Catholic University of America

Dr. Daniel E. Koditschek
Professor, University of Pennsylvania

Matthew England
Vice President of Business Development, Citadel Defense Company

3:30 – 4:30 PM

NEUROSCIENCE

ROOM 151 A/B

Taking New Concepts for Systems Design and Control from Neuroscience to Accelerate Innovation in Artificial Intelligence
Dr. Kelvin S. Oie
Senior Campaign Scientist for Human Sciences, Army Research Laboratory

A Pilot Study to Characterize the Epigenomic Status of the U.S. OEF/OIF War Veterans with PTSD
CPT Derese Getnet, USA
Principal Investigator, Integrative Systems Biology, Army Center for Environmental Health Research

Brain Tissue Mechanics in Blast Loading
Dr. Kurosh Darvish
Associate Professor, Temple University

Variability in Human Head Surrogate Data with Changes to Boundary Conditions in Blunt and Blast Trauma
Abdus Ali
PhD Student, New Jersey Institute of Technology

3:30 – 4:30 PM

HUMAN PERFORMANCE OPTIMIZATION AND ENHANCEMENT

ROOM 150 A/B

Biophysics-based Measuring and Modeling of Social Dynamics
Dr. Lisa Troyer
Program Manager, Army Research Office/Army Research Laboratory

Exoskeletons for Soldier Augmentation: Current Research Perspectives
Karen N. Gregorczyk
Biomech Team and Physical Performance Branch Lead, Army Natick Soldier Research, Development and Engineering Center

Development and Testing of Augmented Reality Command, Control, Communicate, Coordinate (ARC4) for Enhanced Battlefield Situational Awareness
Dr. Eric Gans
Principal Engineer, Applied Research Associates

Warrior Performance Platform (WP2™) for U.S. Navy: Leveraging Best-of-Breed Human Performance Tracking and Analytics Technology to Enhance Navy's Physical Fitness, Wellness, and Nutrition Capabilities
Jake Repanshek
Director of Solutions and Technology, The Informatics Application Group, Inc.

4:30 – 6:30 PM

NETWORKING RECEPTION AND POSTER REVIEW IN EXHIBIT HALL
EXHIBIT HALL C

THURSDAY, AUGUST 23

7:00 – 11:30 AM

REGISTRATION OPEN
PREFUNCTION OF ROOM 146

7:00 – 8:00 AM

NETWORKING CONTINENTAL BREAKFAST
PREFUNCTION OF ROOM 146

CONCURRENT TECHNICAL SESSIONS

8:00 – 9:00 AM

SYNTHETIC BIOLOGY AND LIVING MATERIALS
ROOM 152 A/B

Production of Tunable Nanomaterials Using Assembled Bacteriophage Droplets
Dr. Edward Perkins
Senior Scientist, Environmental Networks and Toxicology, Army Corps of Engineers

Microbial Reactors - Indigenous Feed Stocks to Functional Materials
Dr. Katherine L. Germane
Research Biologist, Army Research Laboratory

Genetic Tools and Synthetic Biology "Parts" for Clostridium Acetobutylicum, a Microbe of Military Interest
Dr. Alexander V. Tobias
Senior Researcher, General Technical Services, LLC

Bioinformatic and Deep-Learning Insight into Engineered DNA at Synthetic Biology Foundries
Dr. Mikhail Y. Wolfson
Senior Software Engineer, Ginkgo Bioworks

8:00 – 9:00 AM

ARTIFICIAL INTELLIGENCE
ROOM 151 A/B

Human Emotion Recognition Using Fused Physiological Signals
Dr. Shaun J. Canavan
Assistant Professor, University of South Florida

Artificial Intelligence and Intelligent Systems: Army Challenges
Dr. Brian M. Sadler
Army Senior Scientist for Intelligent Systems, Army Research Laboratory

Biologically Inspired Processor for Ultra-Low Power Video Surveillance Applications
Dr. Lester A. Foster
Chief Technology Officer, EWA Government Systems Inc.

Implementing Emotions in Cognitive Robots
Dr. Lyle N. Long
Professor, Penn State University

8:00 – 9:00 AM

PANEL: VEHICLE MOBILITY AND ARCHITECTURES

ROOM 150 A/B

Dr. Bruce Brendle
Army Research, Development, and Engineering Command
Moderator

Dion Anglin
Director, Cummins, Inc.

Dr. Paramsothy Jayakumar
Senior Technical Expert, Analytics,Army Tank Automotive Research, Development and Engineering Center

Jason Pusey
Mechanical Engineer, Army Research Laboratory

Dr. Chuanbo Yang
Energy Storage Engineer,
National Renewable Energy Laboratory

CONCURRENT TECHNICAL SESSIONS

9:00 – 10:00 AM

QUANTUM COMMUNICATIONS AND SENSING

ROOM 152 A/B

Schrödinger's Web — Race to Build the Quantum Internet

Dr. Jonathan P. Dowling
Co-Director, Hearne Institute for Theoretical Physics, Hearne Chair Professor of Theoretical Physics Louisiana State University

Director, Institute for Theoretical Physics High-rate Entanglement Generation Using Real Quantum Memories

Dr. Siddhartha Santra
Postdoctoral Research Associate, Army Research Laboratory

Optimal Pulse Schemes for High-precision Atom Interferometry

Dr. Michael H. Goerz
Postdoctoral Fellow, Army Research Laboratory

Quantum-secured Communications Over an Optical Network

Dr. George Siopsis
Professor, University of Tennessee

9:00 – 10:00 AM

PANEL: VERTICAL LIFT

ROOM 151 A/B

Dan Bailey
Army Aviation and Missile Research, Development, and Engineering Center
Moderator

Dr. Mulugeta A. Haile
Research Aerospace Engineer
Army Research Laboratory

Eric Spero
Team Lead
Army Research Laboratory

Dr. Andrew Wissink
Army Aviation and Missile Research, Development, and Engineering Center

9:00 – 10:00 AM

INTELLIGENT SYSTEMS

150 A/B

Deep Learning for Future Army Systems

Dr. Michael Lee
Team Lead, Army Research Laboratory

Tactical Short-Range Radar for Personnel Tracking with Split Brain Autoencoders

Samuel Savage
Software Design Engineer, Alion Science and Technology

Generative Adversarial Networks for Thermal Imagery Data Augmentation

Dr. Lance E. Besaw
Senior Robotics Researcher, Neya Systems

10:00 – 10:30 AM

NETWORKING BREAK

PREFUNCTION OF ROOM 146

CONCURRENT TECHNICAL SESSIONS

10:30 – 11:30 AM

FORCE PROTECTION AND SURVIVABILITY

ROOM 152 A/B

Materials and Manufacturing Advancements to Demonstrate Objective Underbody Protection

Dr. Bryan Cheeseman
Rapid Technology Transition Team Leader, Army Research Laboratory

Advanced Ceramics for Future Soldier Protection Technologies

Dr. Kristopher D. Behler
Senior Material Scientist, Army Research Laboratory

Automating Science to Rapidly Discover Higher Performing Armor Ceramics for Readiness Today

Michael Golt
Materials Engineer, Army Research Laboratory

Forward-Looking, Synthetic Aperture Radar (FLSAR) Concept for Landing in Degraded Visual Environments (DVE)

Dr. Traian Dogaru
Electronics Engineer, Army Research Laboratory

10:30 – 11:30 AM		

POINT OF NEED MANUFACTURING

ROOM 151 A/B

Extrusion-Based, Additively Printed Magnets Outperforming Traditional Injection Molded Magnets

Dr. Mariappan P. Paranthaman
Corporate Fellow and Group Leader, Oak Ridge National Laboratory

Operationalizing Additive Manufacturing to Ensure Warfighter Readiness and Modernization

Jim Zunino
Army Research, Development, and Engineering Command

Material Recycling in 3D Printing/Material Sustainability in Additive Manufacturing

Lynn Ahrens
Student, Ursuline Academy

Dr. Andres Tovar
Professor, Indiana University-Purdue University Indianapolis

Systematic Development of Framework for Validation and Performance Quantification of Additively Manufactured (AM) Replacement Parts for Structural Steel Applications

Thomas Gallmeyer
Ph.D. Student, Colorado School of Mines

10:30 – 11:30 AM

PANEL: ELECTROMAGNETIC SPECTRUM DOMINANCE

ROOM 151 A/B

Dr. Jeffrey Boksiner
Senior Research Scientist, Intelligence and Information Warfare Directorate, Communications-Electronics Research, Development and Engineering Center, Army Research, Development and Engineering Command
Moderator

Ellen L. Holthoff
Chemist, Army Research Laboratory

Eric Holzman
Northrop Grumman Mission Systems

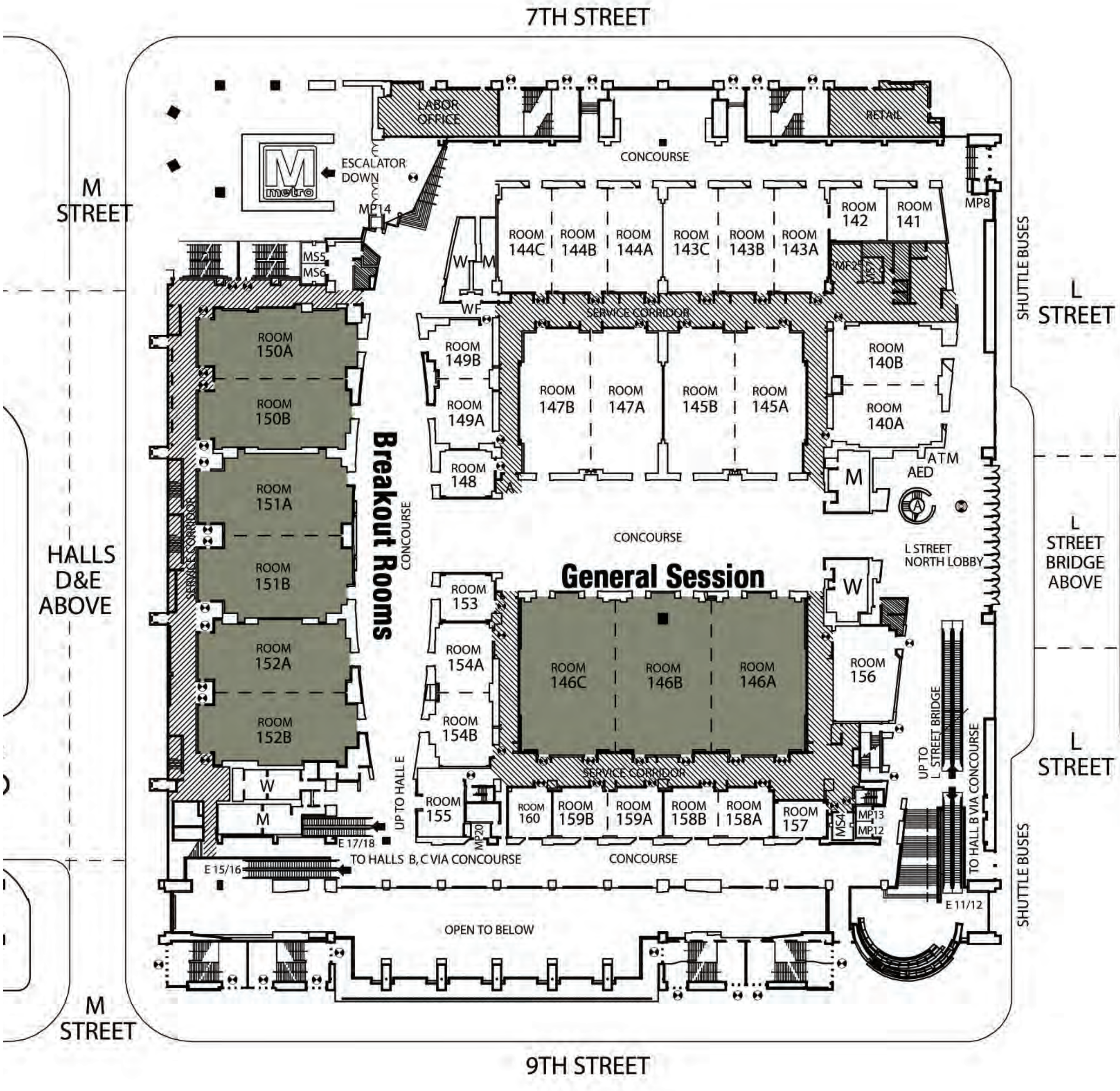
11:30 AM

SYMPOSIUM ADJOURNS

The NDIA has a policy of strict compliance with federal and state antitrust laws. The antitrust laws prohibit competitors from engaging in actions that could result in an unreasonable restraint of trade. Consequently, NDIA members must avoid discussing certain topics when they are together at formal association membership, board, committee, and other meetings and in informal contacts with other industry members: prices, fees, rates, profit margins, or other terms or conditions of sale (including allowances, credit terms, and warranties); allocation of markets or customers or division of territories; or refusals to deal with or boycotts of suppliers, customers or other third parties, or topics that may lead participants not to deal with a particular supplier, customer or third party.

VENUE MAP

STREET LEVEL – LEVEL 1



BIOGRAPHIES

GEN JAMES C. MCCONVILLE, USA

36th Vice Chief of Staff of the Army

Gen. James C. McConville assumed duties as the 36th vice chief of staff of the Army, June 16, 2017. He is a native of Quincy, Massachusetts, and a graduate of the U.S. Military Academy at West Point, New York. He holds a Master of Science in Aerospace Engineering from Georgia Institute of Technology and was a National Security Fellow at Harvard University in 2002.

McConville's command assignments include commanding general of the 101st Airborne Division (Air Assault), where he also served as the commanding general of Combined Joint Task Force-101, Operation Enduring Freedom; deputy commanding general (support) of Combined Joint Task Force-101, Operation

Enduring Freedom; commander of 4th Brigade, 1st Cavalry Division, Operation Iraqi Freedom; commander of 2nd Squadron, 17th Calvary Regiment, 101st Airborne Division (Air Assault); and commander of C Troop, 2nd Squadron, 9th Cavalry Regiment, 7th Infantry Division (Light).

His key staff assignments include the Army deputy chief of staff, G-1; chief of legislative liaison; executive officer to the vice chief of staff of the Army; G-3 for 101st Airborne Division (Air Assault); J5 strategic planner for U.S. Special Operations Command; S-3 for 25th Combat Aviation Brigade; S-3 for 5th Squadron, 9th Cavalry; and S-3 for Flight Concepts Division.

McConville is senior Army aviator qualified in the AH-64D Longbow Apache, OH-58 Kiowa Warrior, AH-6, AH-1 Cobra and other aircrafts. His awards and decorations include two Distinguished Service Medals, three Legions of Merit, three Bronze Star Medals, two Defense Meritorious Service Medals, three Meritorious Service Medals, two Air Medals, the Joint Service Commendation Medal, two Army Commendation Medals, four Army Achievement Medals, the Combat Action Badge, the Expert Infantryman's Badge, the Master Army Aviator Badge, the Air Assault Badge, the Parachutist Badge, and the Army Staff Identification Badge.

McConville and his wife, Maria, have three children serving in the military.

DR. BRUCE D. JETTE

Assistant Secretary of the Army (Acquisition, Logistics and Technology) and Army Acquisition Executive

Dr. Bruce D. Jette was confirmed by the United States Senate as the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)) on December 20, 2017, and sworn into office on January 2, 2018. In this position, he serves as the Army Acquisition Executive, the Senior Procurement Executive, the Science Advisor to the Secretary of the Army, and the Army's Senior Research and Development official. He also has principal responsibility for all Department of the Army matters related to logistics.

Jette leads the execution of the Army's acquisition function and the acquisition management system. His responsibilities include providing oversight for the life cycle management and sustainment of Army weapon systems and equipment from research and development through test and evaluation, acquisition, logistics, fielding, and disposition. He is also responsible for appointing, managing, and evaluating program executive officers and managing the Army Acquisition Corps and Army Acquisition Workforce. In addition, he oversees the Elimination of Chemical Weapons program.

Before his confirmation, Jette served as President and Chief Executive Officer of Synovision Solutions, LLC, an innovative company he founded to provide management and technical consulting, engineering services, and project management in support of military and governmental agencies, as well as commercial industry.

A decorated veteran of 28 years of active duty, Jette retired as a Colonel following a career that included several armor and cavalry company commands, two overseas tours, various staff assignments at the battalion and brigade level, and over two years of operational deployments to Afghanistan, Iraq and Kuwait. Highlights of his previous acquisition service include founding the U.S. Army Rapid Equipping Force; serving as Program Manager for Solider Systems which led to the establishment of Program Executive Office Soldier; and being honored as U.S. Army PM of the Year for his success as Product Manager for all Army airborne electronic warfare systems.

Jette is a graduate of the United States Military Academy with a Bachelor of Science degree in Nuclear Engineering and Chemistry. He also holds both a Master of Science degree and a Doctorate in Electronic Materials from the Massachusetts Institute of Technology. He was an Adjunct Professor at the Edmund A. Walsh School of Foreign Service Security Studies Program at Georgetown University.

His numerous military awards and commendations include the Distinguished Service Medal, Legion of Merit (3), Bronze Star Medal, Meritorious Service Medal (3), Army Commendation Medal, Army Achievement Medal (2), National Defense Medal (2), Operation Iraqi Freedom Campaign Ribbon, Operation Enduring Freedom Ribbon, Army Service Ribbon, Army Overseas Ribbon (2), Parachutist Badge, Army General Staff Award, and Order of Saint Maurice (Legionnaire).

MARY MILLER

Performing the Duties of Assistant Secretary of Defense for Research and Engineering

Mary Miller is performing the duties of the Assistant Secretary of Defense for Research and Engineering. In April 2016, she joined the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics as the Principal Deputy Assistant Secretary of Defense for Research and Engineering. She's responsible for research and development to ensure U.S. technological superiority. She leads and guides development and execution of the science and technology enterprise as well as joint prototyping and experimentation efforts, systems engineering and developmental test policies and procedures.

Miller oversees research at 63 defense laboratories, warfare centers and engineering centers, and prototyping, systems engineering and developmental test efforts for the department. She promotes coordination and cooperation across defense components, between DoD and other federal and non-federal agencies and organizations and ensures technological exchange with allied and partner nations. Miller also serves as the U.S. principal for The Technical Cooperation Program.

Miller served three years as the Deputy Assistant Secretary of the Army for Research and Technology, where she was responsible for policy and oversight of the research and technology programs at 16 laboratories and research, development and engineering centers. She was charged with identifying, developing and demonstrating technology options for soldiers. Her science and technology portfolio covered basic research through development and demonstration of components, subsystems, manufacturing technology and technology system prototypes.

Miller received a B.S. in Electrical Engineering from the University of Washington, an M.S. in Electrical Engineering, Electro-Physics, from George Washington University, and an M.B.A. from the University of Tennessee. She was selected in 2005 to the Senior Executive Service and is Defense Acquisition Workforce Level III certified in Program Management; Engineering; and Science and Technology Management.

DR. THOMAS P. RUSSELL

Deputy Assistant Secretary of the Army (Research and Technology) and Army Chief Scientist

Dr. Thomas Russell was selected as the Deputy Assistant Secretary of the Army for Research and Technology and Army Chief Scientist in April 2016. He is responsible for policy and oversight of the Army's Research and Technology program, which spans 16 Laboratories and Research, Development and Engineering Centers, employs nearly 12,000 scientists and engineers, and has an annual budget that exceeds $2.4 billion.

In this position, Russell is charged with identifying, developing, and demonstrating technology options that inform and enable effective and affordable capabilities for the Soldier. His science and technology portfolio covers basic research to demonstrating component, subsystem, manufacturing technology, and technology system prototypes. It is executed by the Army's research, development and engineering laboratories and centers; academia; and industrial and international partners. Before this assignment, Russell served as cirector of the Army Research Laboratory.

Before joining the Department of the Army, Russell served as Director of the Air Force Office of Scientific Research (AFOSR) from 2010–2013 where he oversaw the management of the Air Force's basic research investments. He managed the AFOSR's investment portfolio, and he transitioned the resulting discoveries to other components of the Air Force Research Laboratory, to defense industries, and to other federal agencies. Russell served as the Director of the Aerospace and Material Sciences Directorate within AFOSR where he was responsible for the Air Force's basic research program in aerospace, chemical, and material sciences.

From 1997-2006, Russell served with the Department of the Navy as the Director, Research, Development, Testing and Evaluation Directorate at the Naval Surface Warfare Center, Indian Head, MD; Section Head, High Energy Materials Section, Chemistry Division, Naval Research Laboratory, Washington, D.C., and as a research scientist at the Naval Research Laboratory, Washington, D.C. and at the Naval Surface Warfare Center, White Oak Laboratory, White Oak, MD.

Russell received a Ph.D.in chemistry, University of Delaware and a B.S. in chemistry, Muhlenberg College. He is the recipient of a Navy Superior Civilian Service award.

EXHIBIT MAP

LOWER LEVEL – LEVEL L

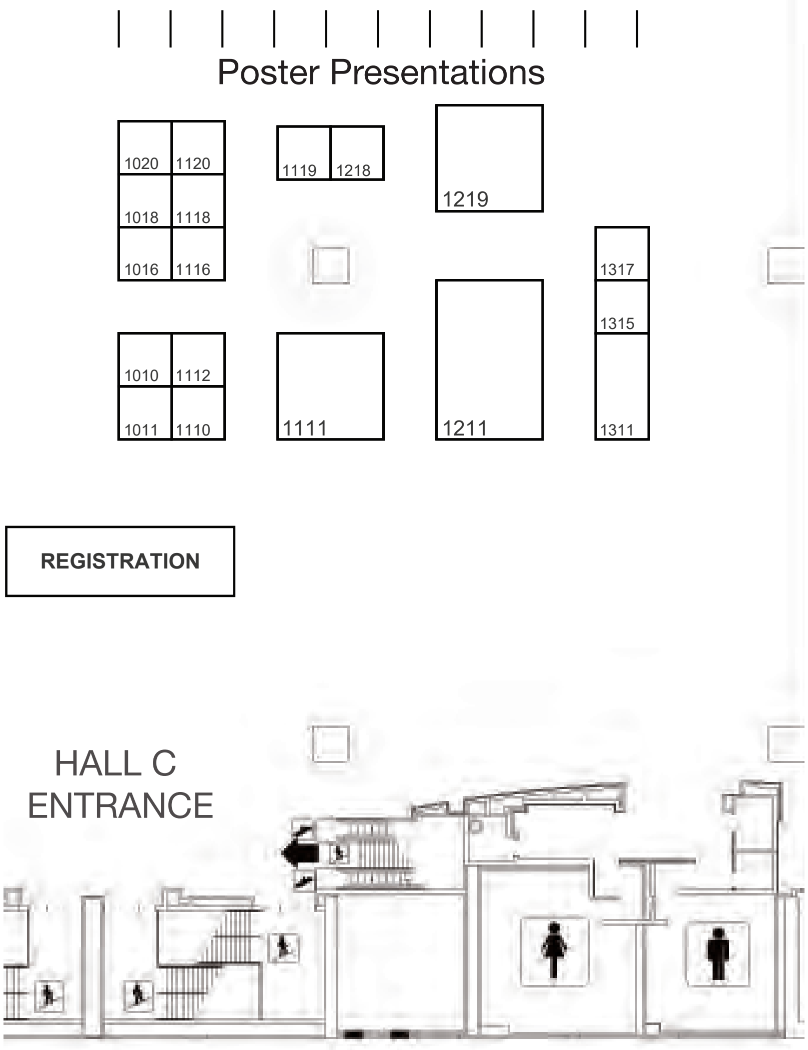


EXHIBIT HALL HOURS

TUESDAY, AUGUST 21
9:30 am - 5:30 pm

WEDNESDAY, AUGUST 22
9:30 am - 6:30 pm

EXHIBITORS BY BOOTH NUMBER

EXHIBITOR DESCRIPTIONS

ARCONIC 1116

Arconic creates breakthrough, multi-material products for the global defense marketplace. Working in close partnership with our customers, we solve complex challenges for all operating environments – air, land, sea and space. Through the ingenuity of our people and cutting-edge advanced manufacturing, we deliver lighter, faster, stronger and more affordable solutions that ensure customer success and meet the critical needs of our armed services.

ASSISTANT SECRETARY OF THE ARMY (ACQUISITION, LOGISTICS AND TECHNOLOGY) 1111

The Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology is committed to ensuring that the American Soldier is the decisive edge in every mission by fielding the finest materiel and services, enabled by cutting edge technology and innovation, to the Warfighters serving our Nation. By placing the Soldier first, our philosophy is grounded in the belief the Army must design, develop, produce and sustain the highest-quality capabilities and deliver them when and where they are needed most. ASA(ALT) is committed to serving its Army, Joint and International partners, and the American public by ensuring responsible and efficient use of the resources with which it is entrusted. ASA(ALT) will continue to provide our Soldiers a decisive advantage today while modernizing to meet future Army needs.

CAMCODE GLOBAL 1120

Camcode Global is the primary provider of Unique Identification (UID) system implementation services for the UK MoD, NSPA and Australian Defense Force. Camcode Global provides durable barcode labels and several other automatic identification and data capture (AIDC) technologies to help organizations manage their assets and comply with item-unique tracking requirements.

CYBERNET SYSTEMS CORPORATION 1020

Cybernet Systems Corporation, a small R&D business, is committed to advancing human performance through advanced technology. Cybernet has successfully completed hundreds of projects for the Department of Defense, NASA, DARPA, and large and small corporations. Cybernet's headquarters in Michigan is focused on developing new technologies including driverless and drive assisted logistical robotics, human-computer interaction, sensors, artificial intelligence, and hardware/mechanical systems. The Florida office focuses on Cybersecurity support and product development.

DEFENSE SYSTEMS INFORMATION ANALYSIS CENTER 1018

The Defense Systems Information Analysis Center (www.dsiac.org) is part of the DoD IAC Enterprise sponsored by the Defense Technical information Center. DSIAC provides technical support to nine defense systems communities of practice through research, information management, document retrieval, core analysis task delivery orders, and our free 4-hour technical inquiry service.

DEFENSE TECHNICAL INFORMATION CENTER (DTIC) 1010

The Defense Technical Information Center (DTIC®) is the premier provider of defense scientific and technical information. DTIC also designs and hosts more than 100 defense-related Web sites, including password-protected Research and Engineering (R&E) Portal, offering DoD personnel, other federal employees and their contractors access to a variety of defense-related technical information.

HOMELAND DEFENSE AND SECURITY INFORMATION ANALYSIS CENTER (HDIAC) 1016

The Homeland Defense and Security Information Analysis Center (HDIAC) is one of three Information Analysis Centers sponsored by the Department of Defense. HDIAC reports to the Defense Technical and Information Center on projects performed on the behalf of the Under Secretary of Defense for Research and Engineering. HDIAC leverages expertise from government agencies, academia, and industry to solve the government's toughest scientific and technical problems. For more info visit www.hdiac.org.

IXIA A KEYSIGHT BUSINESS 1011

Ixia delivers a powerful combination of innovative solutions and trusted insight to support your network and security products, from concept to operation. Whether you are preparing your product for launch, deploying an application, or managing a product in operation, we offer an extensive array of solutions in testing, visibility, and security—all in one place.

NEURO KINETICS, INC. 1110

Neuro Kinetics, Inc. (NKI), the world leader in clinical eye-tracking and non-invasive neuro-functional diagnostic testing, has the Science to See™ neuro-functional biomarkers invisible to the naked eye. For over three decades, NKI has supplied comprehensive neuro-functional diagnostic and assessment tools to neurologists, audiologists, neurotologists, neuro-ophthalmologists, physical therapists, and others worldwide.

SECUREFOUNDRY 1112

We believe a Secure Supply Chain for microelectronics is vital to National Security, Critical Infrastructure, and for the U.S. to remain a global leader in technology. Our security focused methodology ensures raw materials, IP, designs, and products never leave our control, using blockchain technology for full transparency. We provide: Sourcing of Raw Materials, Robust IP Portfolio, Secure Design Environments, Secure Manufacturing Environments, Product Lifecycle Traceability

SITCHAI 1218

Sitch Ai is a technology company focused on Artificial Intelligence and IoT for geospatial and situational awareness. Sitch Ai aims to provide technology that deliverers advanced display intelligent sensors and software that can support the foundation for defense applications to improve soldier lethality and real-time battlefield analytics.

SIX 15 TECHNOLOGIES 1118

Six15 Technologies is a leader in high-resolution head mounted displays and OEM optoelectronic module manufacturing. Located in Henrietta, NY, our production facility manufactures OEM components for thermal imagers; industrial display systems, R&D projects, and custom solutions. Six15 is at the forefront of wearable solutions for Defense, Public Safety, and Medical markets globally with nearly 10,000 wearable displays already sold and over 200,000 optical modules delivered. www.six-15.com

U.S. ARMY ENGINEER RESEARCH AND DEVELOPMENT CENTER (ERDC) 1311

The U. S. Army Engineer Research and Development Center researchers are available to discuss innovative engineering and environmental solutions. Technologies on display include Visualization, Modeling and Material Design solutions: Engineered Resilient Systems, Structural Hardening, 3D Enriched Urban Terrain Visualization and Persistent Surveillance Technologies. ERDC is one of the most diverse engineering and scientific research organization in the world, developing innovative products and services for the nation and the Warfighter.

U.S. ARMY MEDICAL RESEARCH AND MATERIEL COMMAND (USAMRMC) 1219

The U.S. Army Medical Research and Materiel Command is the Army's medical materiel developer, with responsibility for medical research and technology, development, acquisition and medical logistics management. The USAMRMC's expertise in these critical areas as the DOD's only full lifecycle command helps establish and maintain the capabilities the Army needs to ensure readiness and sustain Soldier lethality. Six medical research laboratory commands execute the science and technology program to develop medical solutions for the battlefield with a focus on various areas of biomedical research, including military infectious diseases, combat casualty care, military operational medicine, medical chemical and biological defense, and clinical and rehabilitative medicine.

U.S. ARMY RESEARCH, DEVELOPMENT, ENGINEERING COMMAND (RDECOM) 1211

The U.S. Army Research, Development and Engineering Command leads a global science and technology network beginning with the command's almost 14,000 scientists, engineers and expanding out through more than 500 active domestic and international partnerships with domestic and international academic institutions, small businesses, industry and other government agencies. This gives RDECOM the reach, position, scale and technical expertise to deliver decisive capabilities to lead modernization today while developing leap-ahead technologies for the future.

U.S. ARMY RESEARCH INSTITUTE (ARI) 1315

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) drives scientific innovation to enable the Army to acquire, develop, employ, and retain professional Soldiers and enhance personnel readiness. Research focuses on holistic personnel assessments, leadership competencies for complexity and uncertainty, data science to improve talent management, and team-based personnel assignment and performance. ARI is where Personnel Science Meets Personnel Practice.

ULTI-MATE CONNECTOR, INC. 1119

Ulti-Mate Connector, Inc. technical resources are available to discuss our Nano Connectors and Micro Miniature solutions. Ulti-Mate's reputation for innovation and quality has placed our connectors in many of our country's most advanced missiles, satellite vehicles and navigation systems. We provide design solutions for Military Electronics, Unmanned Systems, Medical and Biotech Industries.

UNANET 1317

Over 1000 organizations trust Unanet cloud software for managing projects, people, and financials in compliance with DCAA regulations. Optimize performance with forecasting, resource planning, project management, time tracking, billing, real-time reporting, and integrated financials.

POSTER PRESENTERS BY AUTHOR

DAY 1 - AUGUST 21

Acosta, J.C. . . . . BOARD 06
Army Research Laboratory
A platform for automatically characterizing network layer attacks in tactical and strategic networks.

Asher, D. ....Board 31
Army Research Laboratory
ALLIES: Agent Learning Leveraging Intelligent Engagement with Soldiers.

Avera, M. . . . . BOARD 30
Army Research Laboratory
High fidelity VTOL flight simulator for UAS platform assessment.

Birdwell, A. . . . . BOARD 15
Army Research Laboratory
Diamond RF electronics for long-range precision fires.

Boteler, L. . . . . BOARD 26
Army Research Laboratory
Co-design and transient thermal mitigation for high performance power electronics packaging in Army vehicles.

Drost, R. . . . . BOARD 11
Army Research Laboratory
Ultraviolet communications and networking.

Folkes, P. . . . . BOARD 09
Army Research Laboratory
Topological materials for energy-efficient electronics.

Hart, R. . . . . BOARD 29
TARDEC
Development of computational models for composite structures to accelerate the design of lightweight next-generation combat vehicles.

Jayakumar, P. . . . . BOARD 27
TARDEC
A novel active learning approach for constructing high-fidelity mobility maps.

Kaplan, L. . . . . BOARD 03
Army Research Laboratory
Social learning theory with uncertain models.

Kim, K. . . . . BOARD 20
Army Research Laboratory
Assessment of a turbocharger performance and reliability in a UAV engine.

Linder, K. . . . . BOARD 02
Orbis Technologies
Multimedia topic modeling for threat actor identification.

Malinovsky, V.S. . . . . BOARD 17
Army Research Laboratory
Optimal rates of quantum repeaters based on two species trapped ions.

Malinovsky, V. . . . . BOARD 18
Army Research Laboratory
Quantum gyro for assured positioning, navigation and timing.

Maryfield, T. . . . . BOARD 13
Cubic Global Defense, Inc.
Small arms precision fire control for reduced engagement time and increased probability of hit.

Michaelis, J. . . . . BOARD 07
Army Research Laboratory
Enabling semantics within IoT services: Extensions to the SPF IoT middleware.

Moore, T. . . . . BOARD 05
Army Research Laboratory
Designing resilient networks using software diversity.

Nair, A. . . . . BOARD 22
Laramie High School
Engineering bacterial guanylate cyclase for optogenetic applications.

Nguyen, A. . . . . BOARD 01
Booz Allen Hamilton
Synthetic data for deep computer vision.

Nusca, M. . . . . BOARD 13
Army Research Laboratory
Modeling and simulation of gun and rocket propulsion systems for Army tactical weapons.

Patil, A. . . . . BOARD 23
Lynbrook High School
Towards dynamic heterogeneous living materials: a comprehensive systems-level framework for global identification of novel molecular interactions and genome-scale modeling of multicellular ecosystems.

Payne, R. . . . . BOARD 10
Washington State University
Analysis of muscle-tendon dynamics in kangaroo rats.

Quraishi, S. . . . . BOARD 19
Army Research Laboratory
Developing the building blocks of a quantum internet with trapped ion qubits.

Reese, C. . . . . BOARD 08
Army Research Laboratory
Quantum position, navigation and timing for GPS denied environments.

Samavedi, S. . . . . BOARD 24
Interlake High School
Designing a Thermostable Cellobiohydrolase: A Novel Approach to Sustainable Ethanol Production.

Sampath, A. . . . . BOARD 14
Army Research Laboratory
Development of nanostructured antireflection coatings for electro-optics infrared systems.

Santhanagopalan, S. . . . . BOARD 28
NREL
Dynamic response of lithium-ion batteries subjected to mechanical failure under high-velocity impact.

Shaw, A. . . . . BOARD 12
RDECOM
A titanium-based igniter system for hand grenade fuzes.

Shurin, S. . . . . BOARD 25
TARDEC
Challenges in military ground vehicle cooling system design and computational fluid dynamics analysis of a notional ground combat vehicle cooling system.

Stead, M. . . . . BOARD 04
Army Research Laboratory
Photonic broadband spectral analysis of a single, sub-microsecond RF pulse in w-band.

Szedlmayer, M. . . . . BOARD 21
Army Research Laboratory
Adverse effects of altitude and fuel properties on UAV propulsion.

Wolff, J. . . . . BOARD 16
Army Research Laboratory
3D-printed interface strengthening via post-print annealing.

DAY 2 - AUGUST 22

Besaw, L.E. . . . . BOARD 12
Neya Systems Division
Applied research associates, dismount following by an unmanned autonomous ground vehicle.

Brawner, K. . . . . BOARD 07
Army Research Laboratory
Adaptive, policy-driven, after action review in the generalized intelligent framework for tutoring.

Chu, K. . . . . BOARD 26
CERDEC
Comparing various capacitor types for high-power applications.

Clausen, J. . . . . BOARD 14
ERDC-CRREL
Soil and meteorological properties affecting thermal IR sensor performance for mine/IED detection.

Collins, P. . . . . BOARD 27
Army Research Laboratory
Army Research Laboratory HBCU/ MI design challenge.

Crone, J.C. . . . . BOARD 18
Army Research Laboratory
Modeling complex neuronal dynamics across network scales.

Felton, M. . . . . BOARD 20
Army Research Laboratory
Phase-modulated power of dendro-somatic current transmissions in a neocortical layer 5 pyramidal neuron model.

Foulis, S. . . . . BOARD 04
Army Research Institute of Environmental Medicine
Overview of the ARIEM Reduction in Musculoskeletal Injury (ARMI) study.

Gutstein, S. . . . . BOARD 08
Army Research Laboratory
HAIL: a human-autonomy crowdsourcing approach to image classification.

Hall, C. . . . . BOARD 28
Army Research Laboratory
Physics and chemistry explorations in STEM.

Hansberger, J. . . . . BOARD 09
Army Research Laboratory
Virtual reality interfaces for exploited media analysis.

Jiang, R. . . . . BOARD 22
Army Research Laboratory
In-situ hydrogen generation and hydrogen fuel cell for future soldier power system.

Johnson, T. . . . . BOARD 21
DCS Corp.
Standardized annotated neurophysiological data repository for the assessment of cognitive state.

Manser, M. . . . . BOARD 25
RDECOM
Nano-enhanced thin-film solar metadevice with large broadband absorption augmentation.

McClure, S. . . . . BOARD 16
Michigan State University
Boron-doped diamond carbon paste electrodes.

McCormick, S. . . . . BOARD 01
Army Research Laboratory
Non-lethal protection concept development for next generation combat vehicle consideration.

McNair, O. . . . . BOARD 02
University of Southern Mississippi
Pneumatic cushions for warfighter protection and enhanced performance.

Orlicki, J. . . . . BOARD 13
Army Research Laboratory
Catechol-functionalized bioinspired synthetic adhesives: probing interfacial control to improve adhesive properties.

Osteen, P. . . . . BOARD 11
Army Research Laboratory
Temporal world models for embodied systems.

Patton, C. . . . . BOARD 10
Army Research Laboratory
Improving accuracy of human behavior modeling for enhanced soldier performance.

Racicot, K. . . . . BOARD 03
RDECOM
Where food science meets nutritional biochemistry: performance nutrition efforts in combat feeding.

Ren, F. . . . . BOARD 15
Temple University
Understanding and tailoring the micro- and nano-mechanical behavior of high-strength fibers for ballistic fabrics.

Sharp, M. . . . . BOARD 05
Army Research Institute of Environmental Medicine
Longitudinal validation of the Occupational Physical Assessment Test.

Shirley, S. . . . . BOARD 17
Little Rock Central High School
Finding a cure for amyotrophic lateral sclerosis: identification of crocin derivative as an inhibitor of protein aggregation.

Tang, X. . . . . BOARD 24
Caddo Magnet High School
Development of an energy recycling system consisting of a thermal-electric generator and a thin film luminescent solar concentrator.

Ter-Gabrielyan, N. . . . . BOARD 31
Army Research Laboratory
Crystalline waveguide lasers for directed energy applications.

Touryan, J. . . . . BOARD 19
Army Research Laboratory
Novel approach for the assessment of cognitive state in complex environments.

Tseng, V. . . . . BOARD 23
Army Research Laboratory
Wireless power transfer using acoustic energy focusing.

Volek, J. . . . . BOARD 06
Ohio State University
Strategies for ketosis and keto-adaptation to optimize human performance and resilience.

FULL ABSTRACT CITATIONS

Acosta, J.C. • Medrano, J.
A platform for automatically characterizing network layer attacks in tactical and strategic networks.

Ahrens, A. • Jefferson, S. • Tovar, A.
Material recycling in 3D printing/material sustainability in additive manufacturing.

Akinwande, D.
Graphene electronic tattoos for imperceptible human monitoring and human-system interfaces.

Ali, A. • Chandra, N. • Hanna, M.J. • Kleinberger, M. • Pfister, B.
Variability in human head surrogate data with changes to boundary conditions in blunt and blast trauma.

Anglin, D. • Major, J.
Advanced Combat Engine (ACE): opposed piston advantages.

Asher, D.E. • Barton, S.L. • Perelman, B. • Schaffer, J. • Waytowich, N.R.
ALLIES: Agent Learning Leveraging Intelligent Engagement with Soldiers.

Avera, M.
High fidelity VTOL flight simulator for UAS platform assessment.

Behler, K.D. • LaSalvia, J.C. • Marvel, C.J. • Shoulders, W.T. • Vargas-Gonzalez, L.R.
Advanced ceramics for future soldier protection technologies.

Benard, W. • Clark, S. • Kott, N. • South, J. • Zunino, J.
Army additive manufacturing: expediting material to materiel.

Besaw, L.E. • Allmen, M.
Dismount following by an unmanned autonomous ground vehicle.

Besaw, L.E. • Lupo, J. • Sgroi, A.
Generative adversarial networks for thermal imagery data augmentation.

Birdwell, A.G. • Ivanov, T.G. • Neupane, M.R. • Shah, P.B. • Weil, J.
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Brawner, K.
Adaptive, policy-driven, after action review in the generalized intelligent framework for tutoring.

Brou, R.J. • Normand, S. • Stallings, G.
Scenario-based, free response assessments of interpersonal leadership skills.

Burguess, V.
Friction stir welded aluminum hull structure material fatigue analysis.

Canavan, S.J. • Fabiano, D.
Human emotion recognition using fused physiological signals.

Cavanagh, J.W. • DeRocco, E.S.
MakerMinded—creating the next generation of manufacturing leaders.

Cheeseman, B. • Lynch, M.
Materials and manufacturing advancements to demonstrate objective underbody protection.

Chu, K. • Atwater, T.B. • Howarth, Y.J.
Comparing various capacitor types for high power applications.

Clausen, J. • Dorvee, J. • Morris, B. • Newman, S. • Williams, C.
Soil and meteorological properties affecting thermal IR sensor performance for mine/IED detection.

Collins, P.D.
Army Research Laboratory HBCU/MI design challenge.

Cox, G.
Scatterable Collaborative Remote Electronic Warfare System (SCREWS).

Crone, J.C. • Boothe, D.L. • Franaszczuk, P.J. • Oie, K.S. • Yu, A.B.
Modeling complex neuronal dynamics across network scales.

Darvish, K. • Assari, S. • Langford, D. • Tierney, R. • Wright, W.G.
Brain tissue mechanics in blast loading.

Dogaru, T. • Le, C. • Sullivan, A.
Forward Looking Synthetic Aperture Radar (FLSAR) concept for landing in Degraded Visual Environments (DVE).

Don, M. • Hamaoui, M.
Localization technologies for swarming munitions.

Douglas, J. • Latorre, P. • Berka, D. • Hurley, C. • Thompson, R.
Advances in Li/CFx non-rechargeable batteries for portable electronic systems.

Dowling, J.P.
Schrödinger's web — race to build the quantum internet.

Drost, R.J. • Arslan, C.H. • Dagefu, F.T. • Verma, G.
Ultraviolet communications and networking.

Dubinskii, M. • Fromzel, V. • Luo, C. • Yin, S. • Zhang, J.
Lasers for DEW based on fully crystalline fibers.

England, M.
Citadel defense company: clearing the skies.

Felton, M.A. • Booth, D.L. • Franaszczuk, P.J. • Oie, K.S. • Yu, A.B.
Phase-modulated power of dendro-somatic current transmissions in a neocortical layer 5 pyramidal neuron model.

Folkes, P.A. • Decoster, G. • Nichols, B. • Taylor, P.J. • Vail, O
Topological materials for energy-efficient electronics.

Foster, L.A. • Niggemeyer, D.
Biologically-inspired processor for ultra-low power video surveillance applications.

Foulis, S. • Hughes, J.M. • Procter, S.P. • Taylor, K.M.
Overview of the ARIEM Reduction in Musculoskeletal Injury (ARMI) Study.

Gallmeyer, T. • Dahal, J. • Neuchterlein, J. • Stebner, A. • Thyagarajan, R.
Systematic development of framework for validation and performance quantification of Additively Manufactured (AM) replacement parts for structural steel applications.

Gans, E. • Bennett, M.D. • Roberts, D.C.
Development and testing of Augmented Reality Command Control Communicate Coordinate (ARC4) for enhanced battlefield situational awareness.

George, M.C.
Army science and technology to support long range precision fires modernization.

Germane, K.L. • Perisin, M.A. • Sund, C.J.
Microbial reactors - indigenous feed stocks to functional materials.

Getnet, D. • Gautam, A. • Hammamieh, R. A. • Jett, M. • Marmar, C. • Yang, R.
A pilot study to characterize the epigenomic status of the US OEF/ OIF war veterans with PTSD.

Goerz, M.H. • Kasevich, M.A. • Kunz, P.D. • Malinovsky, V.S.
Optimal pulse schemes for high-precision atom interferometry.

Golt, M. • Ashkin, D. • Campbell, J. • Palicka, R.
Automating science to rapidly discover higher performing armor ceramics for readiness today.

Gregorczyk, K.N. • O'Donovan, M.P.
Exoskeletons for soldier augmentation: current research perspectives.

Gutstein, S. • Bohannon, A. • Lawhern, V. • Slayback, D.T. • Waytowich, N.
HAIL: a human-autonomy crowdsourcing approach to image classification.

Haile, M.A.
Risk-adaptive maneuver for enduring operation.

Hall, C.M.
Physics and Chemistry Explorations in STEM.

Hansberger, J.T.
Virtual reality interfaces for exploited media analysis.

Hart, R.J.
Development of computational models for composite structures to accelerate the design of lightweight next generation combat vehicles.

Heintz, A.M. • Colachis, M. • Ganzer, P. • Shqau, K.
Enhancing warfighter performance with non-invasive neurostimulation enabled by dry skin electrodes.

Holthoff, E.L. • Bickford, J.R. • Cho, P. • Pellegrino, P.M.
Chip-scale optical phased arrays to enable reliable communications.

Huisman, T.
Immersive training: using sound as a training tool.

Jayakumar, P. • Choi, K. • Funk, M. • Gaul, N. • Wasfy, T.
Development of a stochastic mobility map for next generation NATO reference mobility model.

Jayakumar, P. • Marple, G.R. • Mechergui, D. • Veerapaneni, S. • Wasfy, T.
A novel active learning approach for constructing high-fidelity mobility maps.

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Standardized annotated neurophysiological data repository for the assessment of cognitive state.

Jones, E.M. • Ryan, K.J.
Tactical augmented reality, precisely where you need it: bringing registered AR to the field.

Kaplan, L. • Jadbabaie, A.
Social learning theory with uncertain models.

Kaplan, L. • Chen, F. • Cho, J. • Sensoy, M. • Sullivan, P.
Uncertainty-aware artificial intelligence for more effective decision making.

Kapteyn, H.C. • Murnane, M.
Bright tabletop source of coherent x-rays: new directions in materials and biological science.

Kilic, O. • Fathy, A.E. • Plaku, E.
Drones with reconfigurable phased array antennas for manned-unmanned teaming operations.

Kim, C.
Machine reasoning for determination of threat level in irregular warfare.

Kim, K. • Clerkin, P. • Kruger, K. • Kweon, C.M. • Szedlmayer, M.
Assessment of a turbocharger performance and reliability in a UAV engine.

Klett, J.W. • Greiner, N.
Phase change material filled graphite for electronics cooling in transient environments.

Koditschek, D.E.
Science of embodied innovation, learning and control.

Kravitz, A.
Large virtual aperture hyper-spectral NANO-SAT formations for operationally responsive space-based identification and tracking of fuel vapors, lethal gasses, and other hyperspectral applications.

Lee, M. • Edwards, S. • Hyatt, J.S. • Kirk, K. • Mark, E.
Deep learning for future Army systems.

Linder, K.
Multimedia topic modeling for threat actor identification.

Long, L.N. • Kelley, T.D.
Implementing emotions in cognitive robots.

Malinovsky, V.S. • Jiang, L. • Monroe, C. • Muralidharan, S. • Santra, S. • Soderberg, K.
Optimal rates of quantum repeaters based on two species trapped ions.

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Boron-doped diamond carbon paste electrodes.

McCormick, S. • Adler, E. • Gamizina, D.
Non-lethal protection concept development for next generation combat vehicle consideration.

McNair, O. • Piland, S. • Wiggins, J.
Pneumatic cushions for warfighter protection and enhanced performance.

Merkle, L. • Dubinskii, M.
New process for efficient laser pumping: three-for-one cross-relaxation.

Michaelis, J.R.
Enabling semantics within IoT services: extensions to the SPF IoT middleware.

Miller, C.
Resilient communications with hybrid adaptive networking.

Mitchell, G. • Hedden, A. • Galanos, D. • Anthony, T. • McElrone, B.
Agile and reconfigurable digital radar technology for air and missile defense.

Moore, T. • Cho, J.
Designing resilient networks using software diversity.

Nair, A.S.
Engineering bacterial guanylate cyclase for optogenetic applications.

Nakano, V.M. • Ramesh, K.T.
Developing the materials-by-design workforce at the Hopkins Extreme Materials Institute.

Nguyen, A. • Lashbrook, K.R. • Donahue,K. • Gilmer, G.
Synthetic data for deep computer vision.

Nusca, M. • McQuaid, M.J. • Schmidt, J.R.
Modeling and simulation of gun and rocket propulsion systems for Army tactical weapons.

Oie, K.S. • Boothe, D.L. • Crone, J. • Felton, Jr. • M.A. • Franaszczuk, P.J.
Taking new concepts for systems design and control from neuroscience to accelerate innovation in artificial intelligence.

Orlicki, J. • Bartucci, M.A. • Flanagan, D.P. • Lenhart, J.L. • Radzinski, S.C.
Catechol-functionalized bioinspired synthetic adhesives: probing interfacial control to improve adhesive properties.

Osteen, P. • Owens, J.L. • St. Amant, R.
Temporal world models for embodied systems.

Paranthaman, M.P.
Extrusion based additively printed magnets outperforming traditional injection molded magnets.

Patil, A.
Towards dynamic heterogeneous living materials: a comprehensive systems-level framework for global identification of novel molecular interactions and genome-scale modeling of multicellular ecosystems.

Patterson, M. • Mosier, M.
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Shivers, B.L. • Brozoski, F.T. • Chancey, V.C. • Estep, P.N. • Madison, A.M.
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Stead, M. • Zhou, W.
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Touryan, J. • Gordon, S.M.
Novel approach for the assessment of cognitive state in complex environments.

Troyer, L.
Biophysics-based measuring and modeling of social dynamics.

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Wright, W.G. • Cheever, K. • Langford, D. • Mansell, J. • Tierney, R.
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Zhou, G. • Church, C. • Shaaban, A.H.
Active Cooling Thermally Induced Vapor-Polymerization Effect (ACTIVE)

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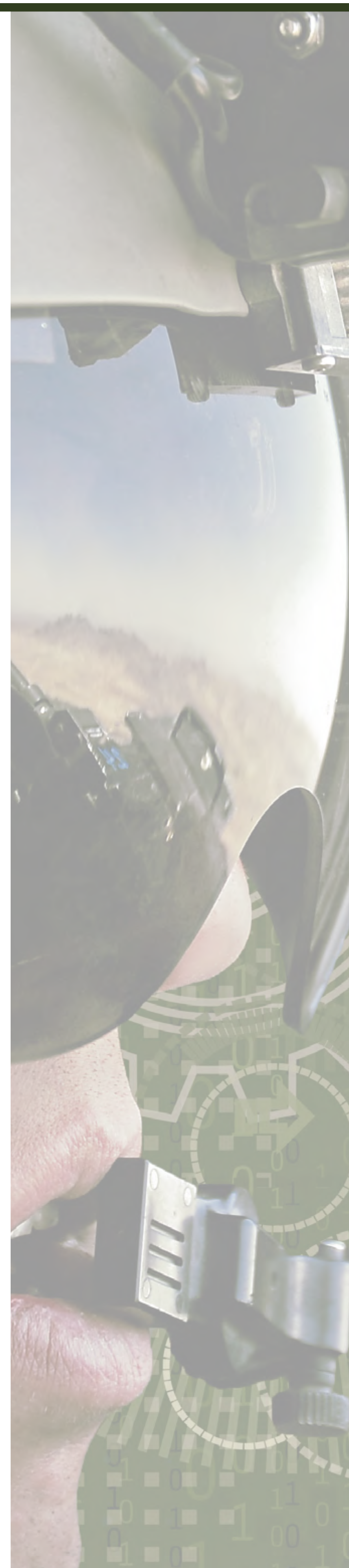


Drone Based Autonomous Antenna Swarms

Communications and Control Aspects for Manned-Unmanned Teaming

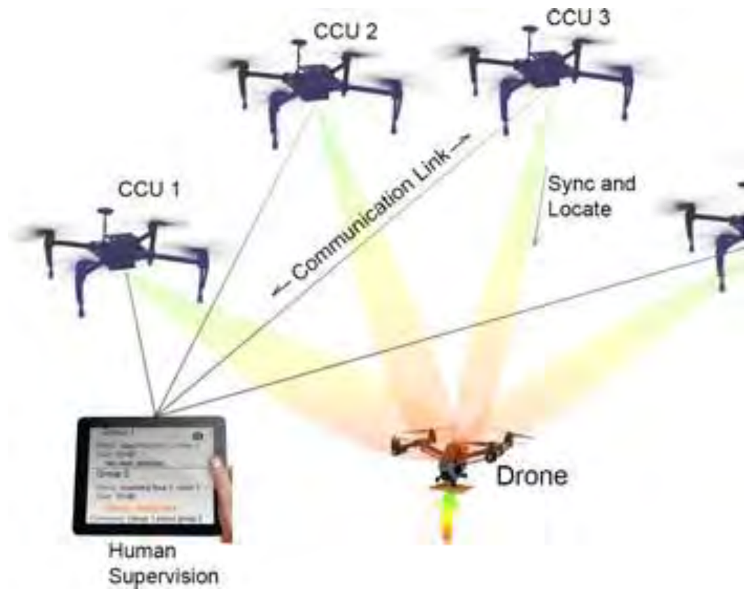
Ozlem Kilic
The Catholic University of America

- The Catholic University of America:
  - Ozlem Kilic - Antenna system design, swarm optimization
  - Erion Plaku – Swarm motion planning, optimization
- University of Tennessee, Knoxville
  - Aly E. Fathy – Radar system design, synchronization and localization

Interdisciplinary Collaboration

Objectives

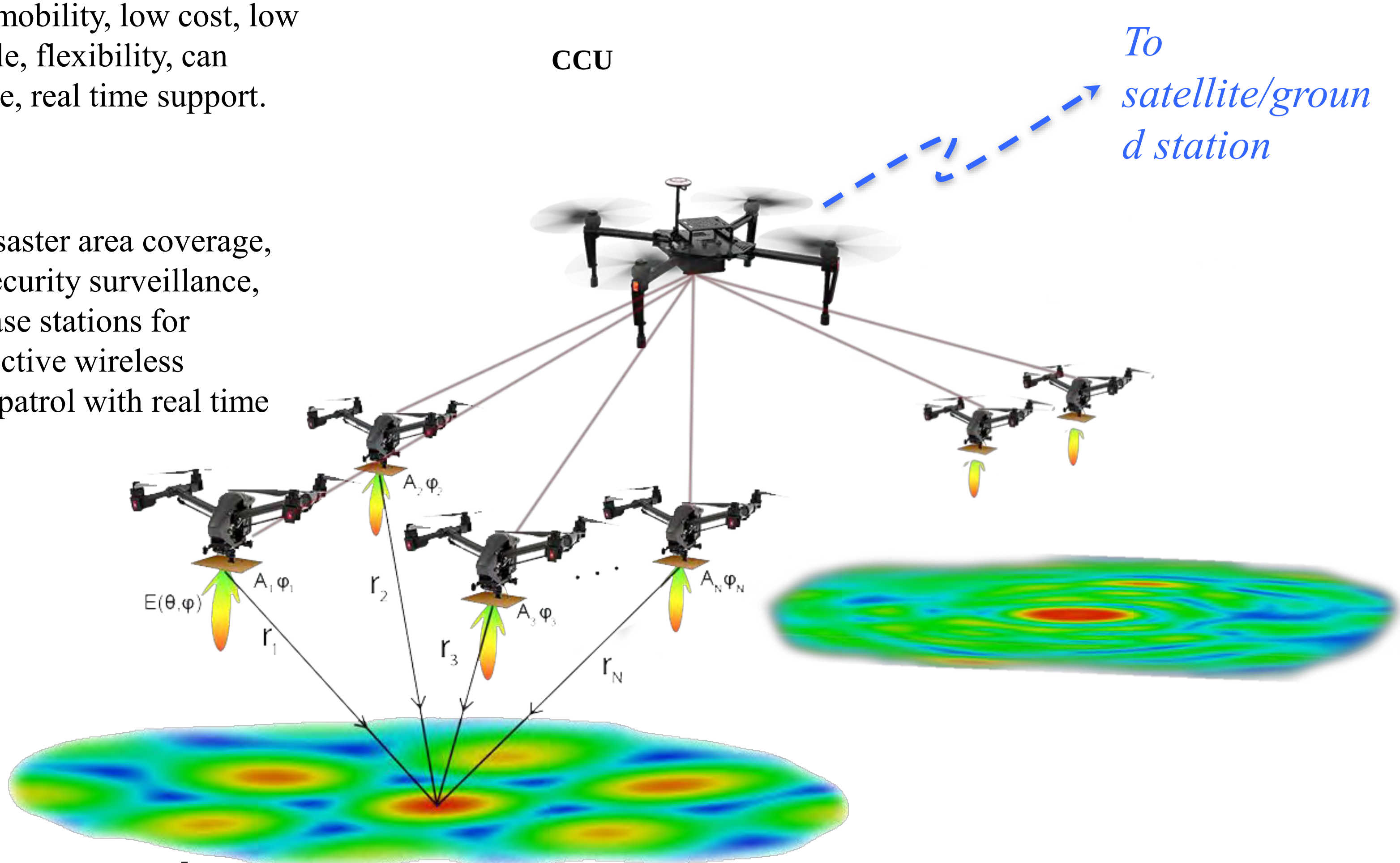
- Develop an autonomous, distributed system to remotely sense, image, or monitor an activity or a particular property of interest in a difficult to reach/hostile environment
- Use microwave technology (high penetration of barriers, night time use, privacy)



Drones provide platform for beam switching between satellites/base stations on the ground.

ADVANTAGES:
Adjustable altitude, mobility, low cost, low infrastructure, reliable, flexibility, can provide high data rate, real time support.

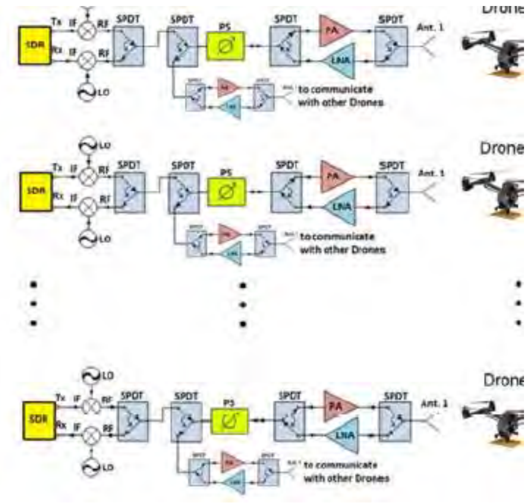
APPLICATIONS:
Communications, disaster area coverage, search and rescue, security surveillance, agriculture, flying base stations for reliable and cost effective wireless connectivity, border patrol with real time support

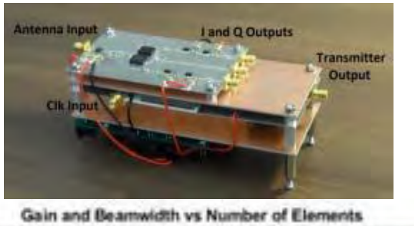


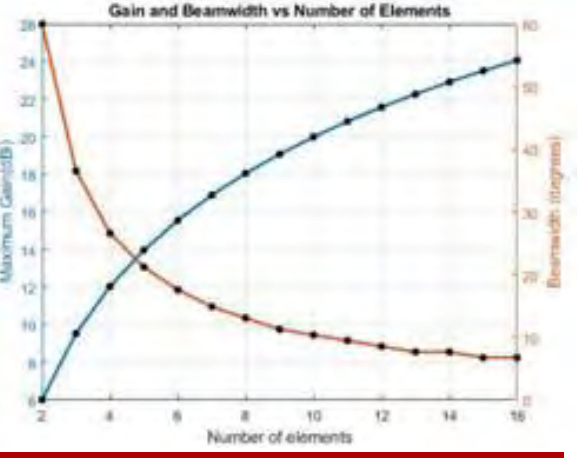
Concept

Antenna System

- The antenna array system is composed of multiple single-antenna drones
- Reconfigurable using relative spacing, number of elements, and phase shifters.
- Not limited by space constraints
- Gain along a given direction is controlled via relative drone positioning and/or phase are adjustments.







- CCU – satellite/ground station

The connection to ground is the bottle neck of drone technology, and needs to be done in real time. Improving the connection would improve RF link budgets

- Swarm – CCU
- Inter-swarm

for coordination, interference mitigation, relaying, routing in the air

- Swarm – ROI (region of interest)
  - *Multiple drones can be used as an aerial antenna array and can effectively provide wireless service to ground users.*
  - *Service time is minimized by optimizing the wireless transmission time and control time needed for movement and stabilization of drones.*
  - *Transmission time can be minimized by increasing the array gain upon optimizing the drone spacing.*
  - *A tradeoff needed to minimize control time, transmission time, serving multiple users by adjusting number and location of drones*
  - *Synchronization with GPS would allow precise localization*

Communications

- Interference
- Handover and movements
- Resource management
- Security and privacy
- Energy efficiency
- Path planning
- Drone antennas – small, light weight, robust

Challenges and Limitations

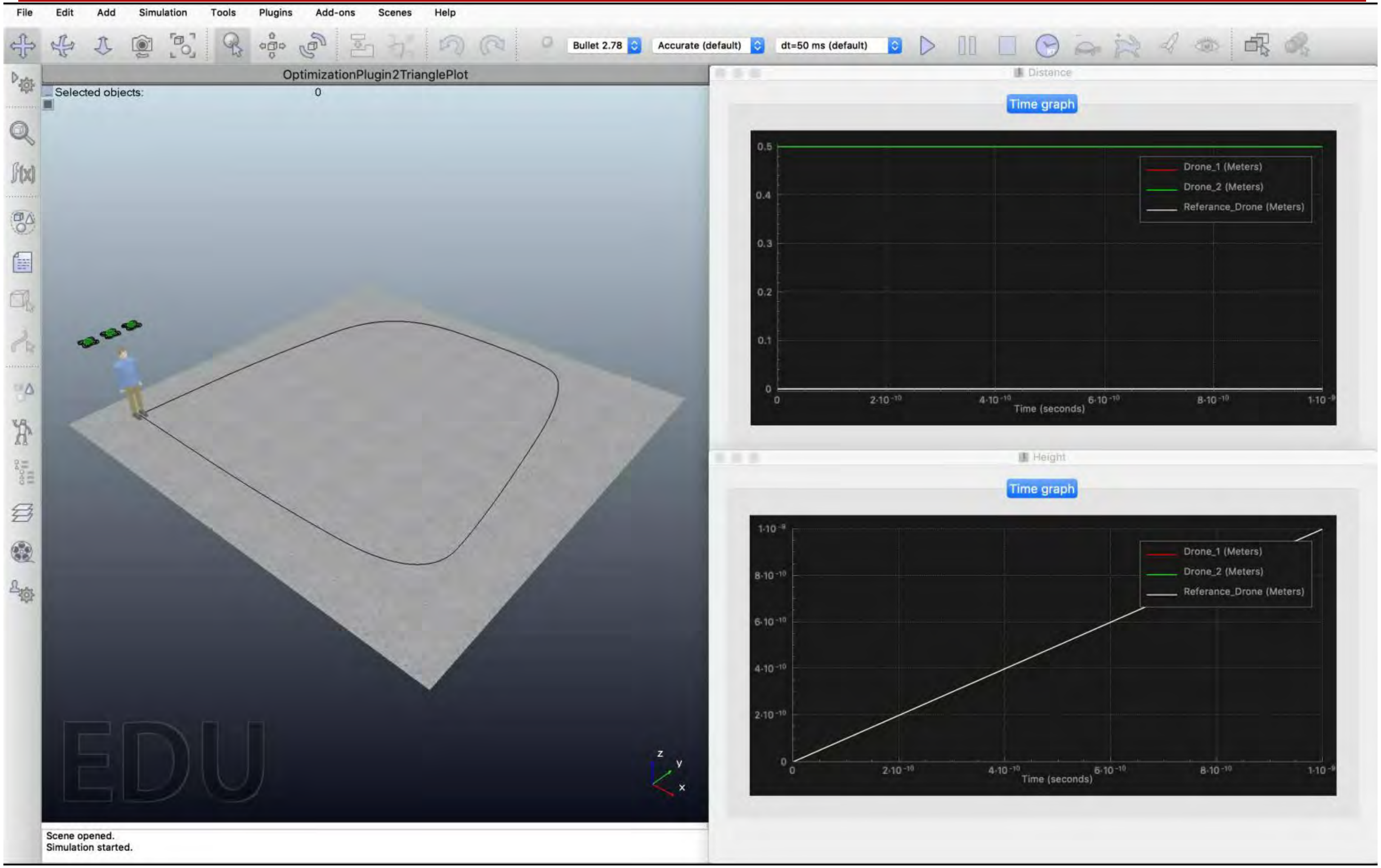
- Use of electronically scanned antennas: Maximize: range, persistence, data rate, and lifetime.
- Better solution when fixed beam or mechanically gimbaled apertures not viable.
- Advantages: low mass, mechanical simplicity, directing energy into a spot, higher efficiency, better autonomous flight duration.
- A ground station can follow a planned route of the drone, steering its own beam, or the drone can maintain connectivity to one or various ground stations that are located in fixed or known positions.

Our Approach

- Illustration of how the proposed system could be used in a disaster-recovery scenario
  - Approach partitions UAVs into smaller groups, assigns tasks, and plans motions
  - Objective is to quickly inspect the entire area
  - System actively communicates with the human supervisor providing critical feedback and responding to new instructions

Application – Disaster Rescue

Application - Defense



Real Time Coverage

ASTRAPI®

Exponential Communication

Jerrold Prothero, Ph.D.

THE ARMY, SMALL COMPANIES, & BIG INNOVATION

NDIA Army Science & Technology Symposium & Showcase

August 21, 2018

Astrapi Corporation

Dallas, TX

The Army & Transformative Technologies

Benefit: Transformative Technologies Give Our Warfighters the Edge

- Big innovation leads to big advantage
- Lack of innovation erodes advantage
- To lead in anything is to lead in innovation

How

- Commercial industry innovations can become transformative tools on the battlefield (smartphones, WiFi, drones)
- Tap into rapid industry innovation cycles (versus long DoD development cycles)

Difficulty: Transformation is Hard to Nurture & Integrate

- Not compatible with long Army purchasing cycles
- The Army prioritizes rapid battlefield deployment. As a result, there is limited funding for R&D below TRL 6, which is where disruptive innovations come from

Onboarding Transformative Technologies

The Army Challenge for Small Companies

- Transformative innovation is most likely to come from small companies
    - How to find them?
    - How to validate them?
    - How to develop and integrate them?

The Small Company Challenge for the Army

- How does a small company engage with the Army?

What is the Right Path for Mutual Success?

- Create an innovation framework
- The Red Queen Problem – Innovation in the DoD and Intelligence Community
    - Steve Blank, innovation expert
    - Continuous innovation pipeline, not separate activities
    - Different horizons with different levels of risk
    - Application of scientific method to innovation

Some Ways the DoD Has Encouraged Small Innovative Firms

- Increasing use of Other Transaction Authority (**OTA)**. Less onerous contracts for non-traditional contractors.

- Increasing use of OTA-based **Industry Consortia**. Incentive for small, non-traditional contractors to bring disruptive innovations to DoD. Examples:
  - System of Systems Security Consortium (SOSSEC)
  - Consortium for Command, Control, Communications… (C5T)
  - National Spectrum Consortium (NSC)

- **SBIR** programs, including new formats aimed at rapid innovation

- Encouragement of **matchmaking** between large contractors and small businesses (in a consortia environment) to help bring small company innovations to production

- Increasingly **modular approach** to systems development permits small company innovations at the component, rather than system level (JCAUS)

Astrapi: A Case Study

Innovation: "Spiral Modulation"

- Potential for dramatically higher spectral efficiency
- Currently TRL-4
- More data throughput, lower signal power requirements, less bandwidth usage, longer battery life, lower latency

Potential Types of Benefits

- Higher data throughput
- Better Size, Weight & Power (SWaP)
- Less spectrum required
- Lower latency

Support

- National Science Foundation (NSF) SBIR Phase I (#1621082)
- NSF SBIR Phase II (#1738453)
- Air Force Special Topics SBIR Phase I (UAS communications)
- Army xTechSearch Phase I
- $2.2m in private investment

Types of Use Cases

Very Broad Potential Applicability

- Increase capacity of field satellite links and resistance to rain fade
- Increase capacity of High Capacity Line of Site (HCLOS), point to point radios
- Reduced SWaP requirements for hand-held radios
- Reduced SWaP requirements for UAS radios
- Increase resistance to noise for radios in urban warfare environments

Specific Application: UAS

- UAS communications a key issue for the DoD
- Army Roadmap for UAS 2010-2035
    - Five levels of interoperability
    - All critically dependent on communication
- UAS only as good as their data link
- Spectral efficiency affects UAS control, security, data throughput
- Astrapi technology potentially applicable across Wasp, SRR, MRR, LRR systems

Contacts

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Technical resources
http://www.astrapi-corp.com/technology/white-papers/

Website
http://www.astrapi-corp.com/

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

DIGITAL RADAR TECHNOLOGY FOR AIR AND MISSILE DEFENSE

Dr. Gregory Mitchell, Dr. Abigail Hedden, Daniel Galanos, Theodore Anthony, Brendan McElrone

U.S. Army Research Laboratory

21 AUG 2018

AMD RADAR MODERNIZATION CHALLENGES

Images source: internet (unclassified)

Legacy radar platforms are stove piped:

- Custom hardware, custom software, single mission
- Upgrades don’t propagate across multiple platforms
- Platforms can’t network capabilities
- Not scalable or sustainable for Army modernization priorities

Can’t adapt to dynamic environments:

- Not jamming resistant, not frequency agile
- Can’t respond to new threats without upgrades

Calibration:

- High precision in-situ calibration is essential for future success of digital radar

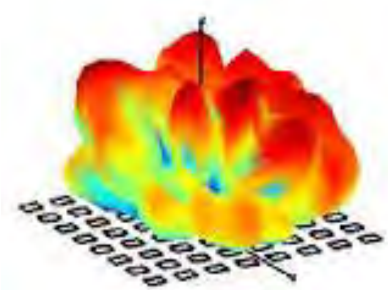
DIGITAL COMMON ARCHITECTURE SOLUTION

Digital Radar can be an Open Architecture Modular Solution

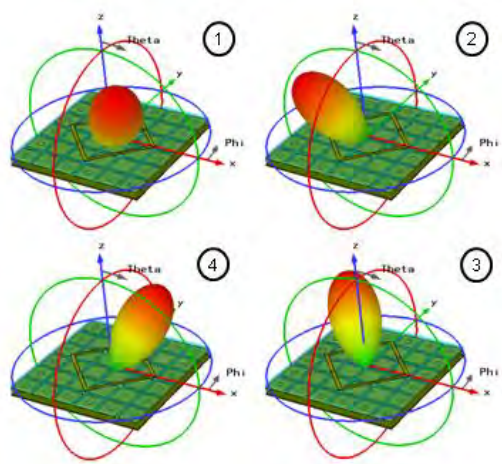
- Small, scalable, lightweight form factor ➡ **freedom of movement, mobile radar**
- Repairs and upgrades propagate across platforms ➡ **sustainment of operations**
- Networking between radar platforms ➡ **situational understanding, wide area security**
    - Common architectures mean tri-service sharing of assets and information

Individual Control of ESA at the Element Level ➡ In-situ Calibration

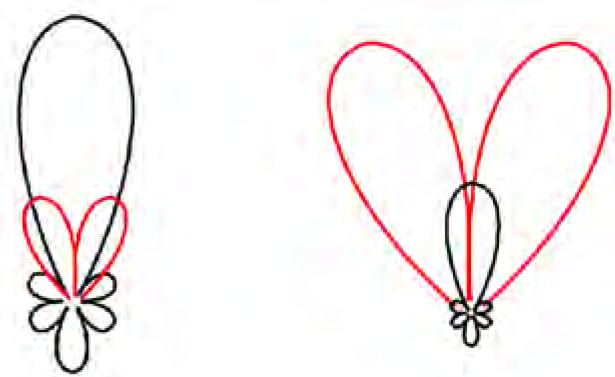
- Continuous calibration ensures continuous optimal performance
- Adaptable to emerging threats and changing operational environment



Uncalibrated Radar



Calibrated Radar ➡



Beam Shaping to Defeat DRFM/Jamming

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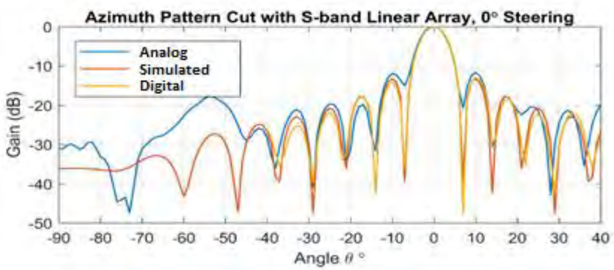
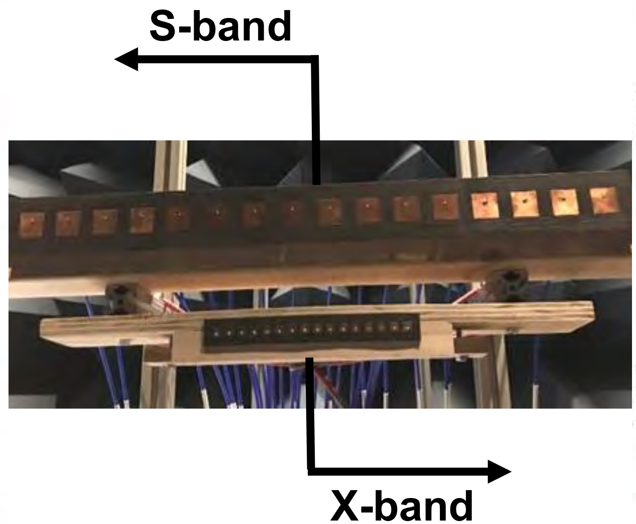
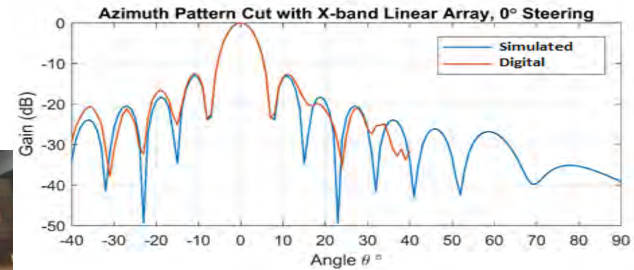
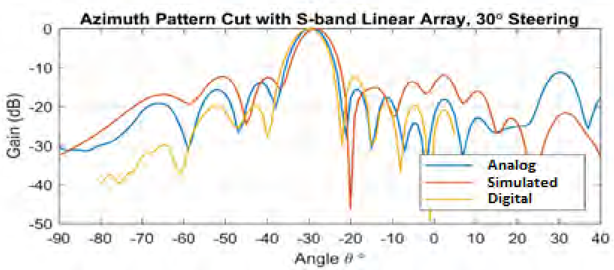
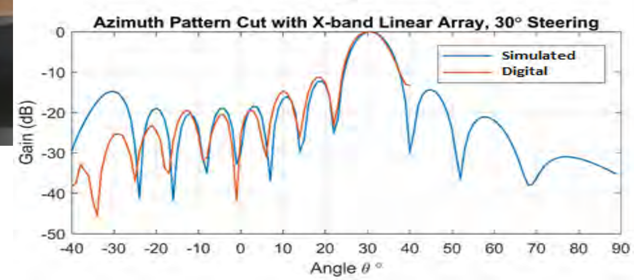
BEAMFORMING AND BEAM STEERING







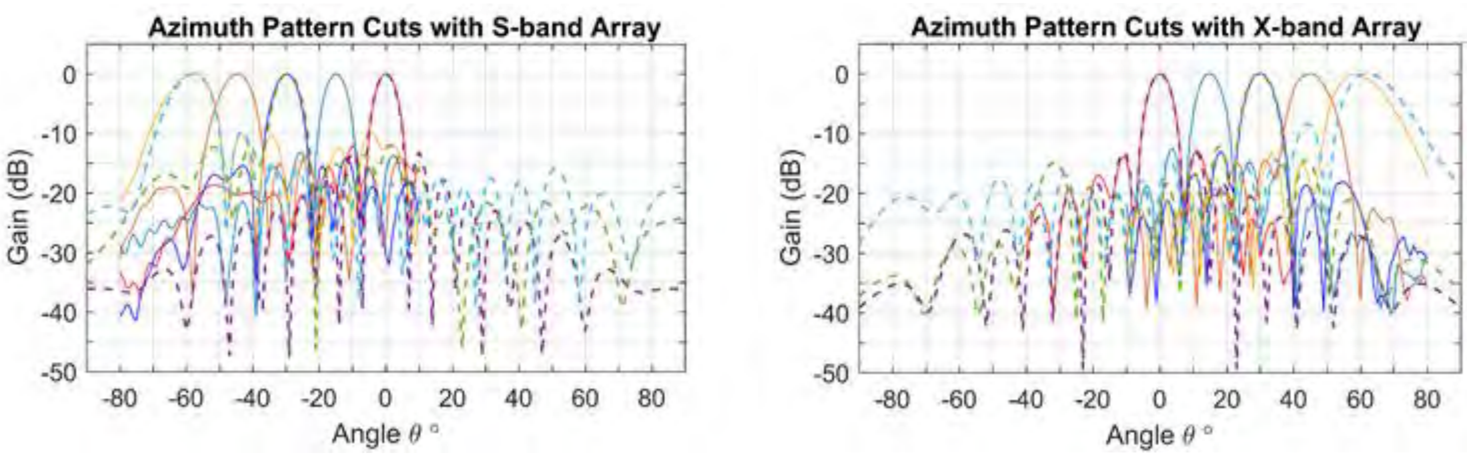




Compared analog vs. digital beamforming and beam steering for two frequency bands:

- Used 16 element linear arrays at S- and X-band
- Simulated results represent a perfectly calibrated array
- Beam steering was tested from 0° to 60° off boresight
- Digital module matches simulated results

DIGITAL BEAMFORMING & BEAM STEERING

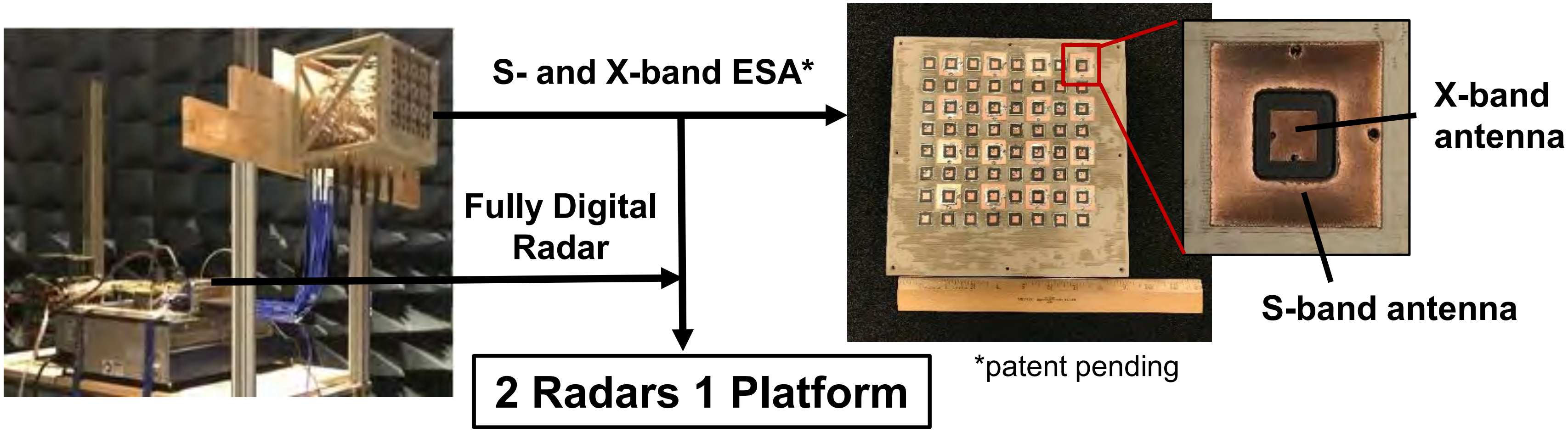


Multiple simultaneous beams at S- and X-band:

- Digitally steered 4 simultaneous receive beams
- Beams steered up 0° to 60° off boresight
- Excellent agreement between measured and simulated patterns
- Coherently formed and steered beams of two separate radars

Digital Module Demonstrates Re-configurability to support Multiple Radar Systems

ARL DUAL-BAND PROTOTYPE



ARL Demonstrates shared Radar Frequencies with a Single Antenna:

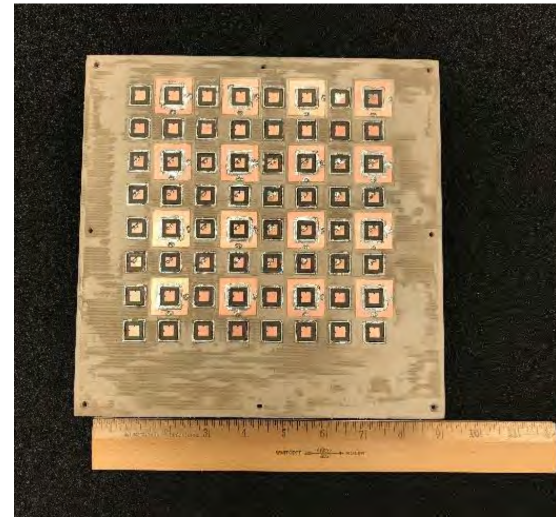
- Dual-band antenna (S- & X-band), in the same aperture
- Dual-polarization (V- & H-) flexibility for ground-based radar
- **Similar scaled array performance as currently fielded CTA and AMD radars**
  - **Return loss: -10 dB or better, gain 37 - 40 dB, 3.0° beam width**
- Simultaneous operation of digital dual band systems at S- and X-band frequencies
- Antenna allows full beam control at both frequencies at the same time

ARL has Demonstrated Dual-Band Functionality for Multi-mission Radar

S- AND X-BAND IN ONE ANTENNA

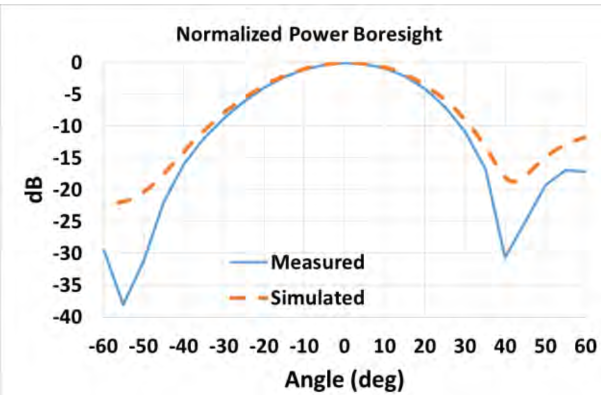
Demonstrated capability at 3.56 GHz and 10.3 GHz:

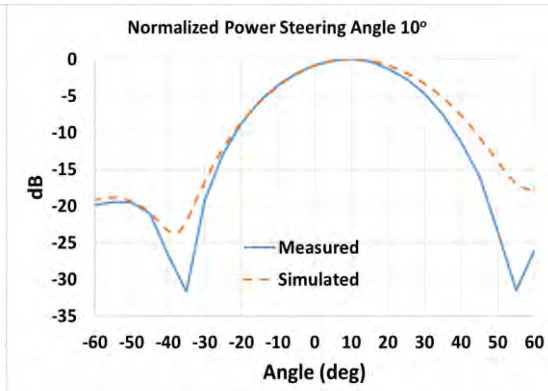
- Digital transceiver module excites dual-band antenna
- Both V- and H-pol data
- Multiple steering angles (0° to +/- 30°)
- Observed pattern cuts match simulations

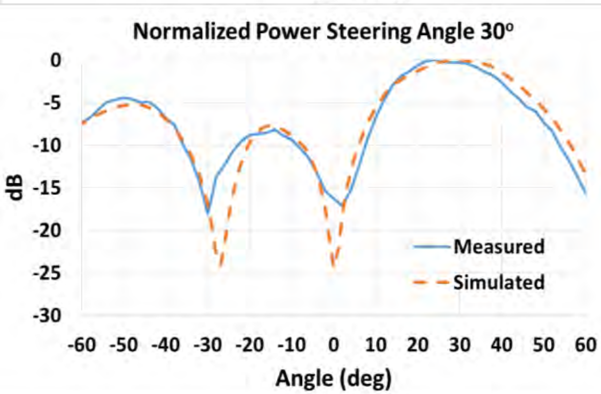


S- and X-band ESA*

*patent pending







Dual Band and Dual Polarization Functionality in a Common Digital Architecture

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SUMMARY

Digital Radar Capabilities:

- **Modular solution with a common architecture across platforms**
- Formation and scanning of multiple beams, null steering, in-situ adaptability
- Propagates repairs and technology upgrades across all platforms
- Networking between radar platforms
- Small, scalable, lightweight form factor

ARL Novel Dual-band ESA:

- **Combines the S- and X-band antennas into a single platform**
- Simultaneous S- and X-band operation
- H- and V- polarization diversity in a thin planar structure
- Needs novel material manufacturing methods to scale design

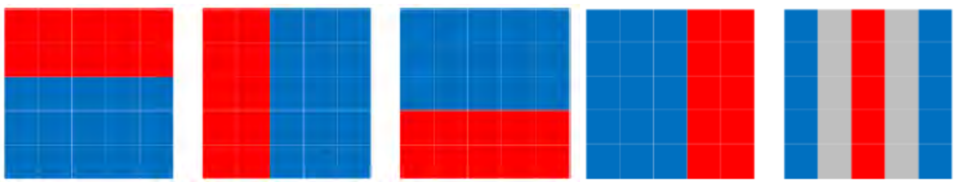
Calibration:

- **Leverage re-configurability and computational capabilities inherent to digital arrays**
- High precision calibration is essential for digital array technology viable
- Need calibration techniques that are wideband and computationally efficient
- Over the air calibration not feasible in the field

FUTURE WORK

Digital Calibration Algorithms:

- ESA radar functions require high element level phase accuracy
- ARL is investigating in-situ calibration algorithms using digital radar
- These algorithms will be system agnostic and adaptable



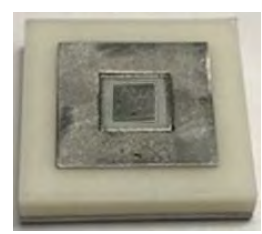
Nearest Neighbor Technique → Array elements act as transmitters to calibrate to their nearest neighbors in place over an over the air transmitter

Additive Manufacturing for Antennas:

- New antennas lead to increasingly complex geometries with tight tolerances
- Traditional manufacturing techniques can’t meet these requirements
- ARL is leading research on 3D printing of antennas and RF devices
  - Develop electromagnetic materials compatible with 3D printing
  - 3D printing complex antenna designs

Integrated multi-mission capabilities lead to complex antenna designs

Complex hybrid material 3D printed antenna prototypes →



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Backup Slides

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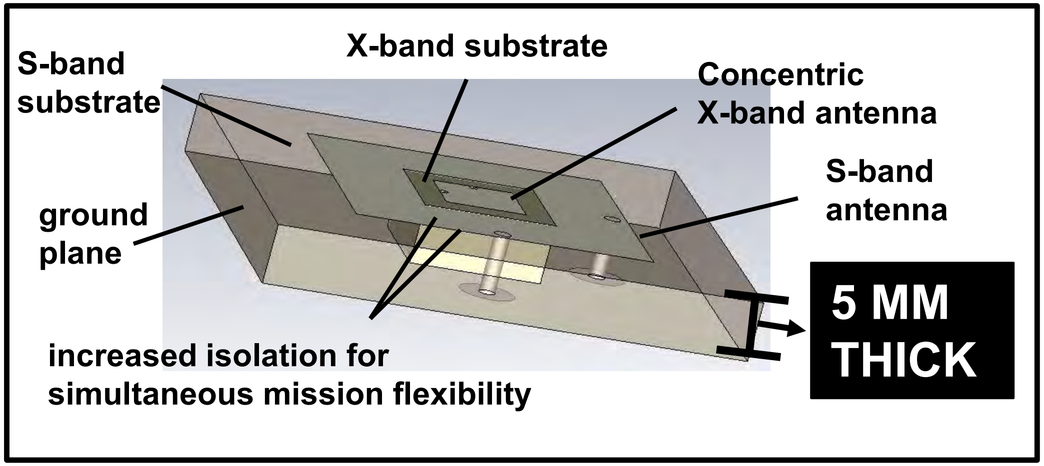
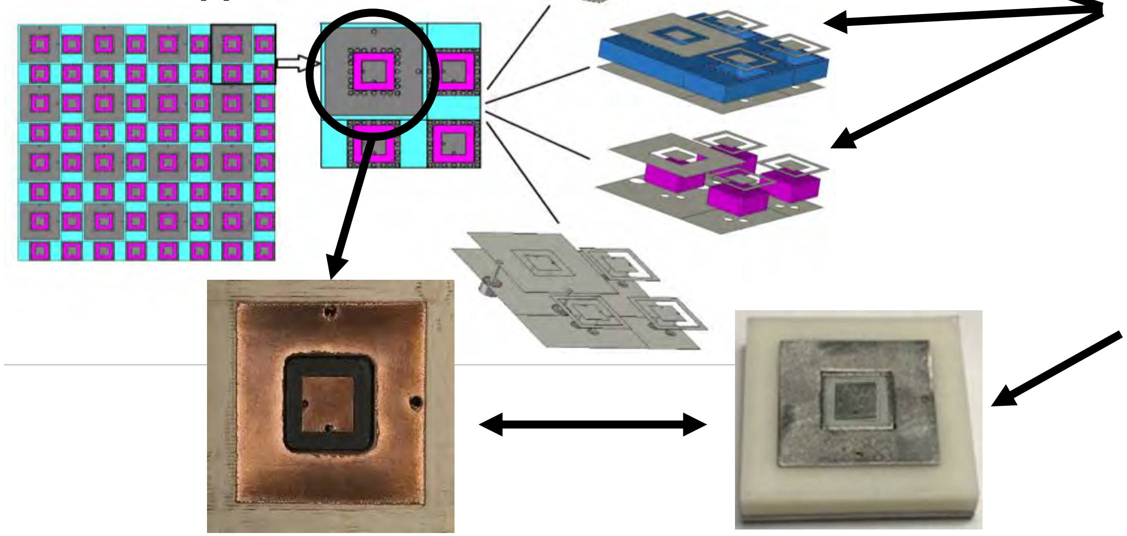
3D PRINTED ANTENNA DESIGN



Phased array for Multi-Mission applications:



Non-traditional antennas:

- Simultaneous Multi-Mission capabilities
- Frequency and polarization agility
- Thin, lightweight, planar

Integrated, multi-mission capabilities lead to complex designs:

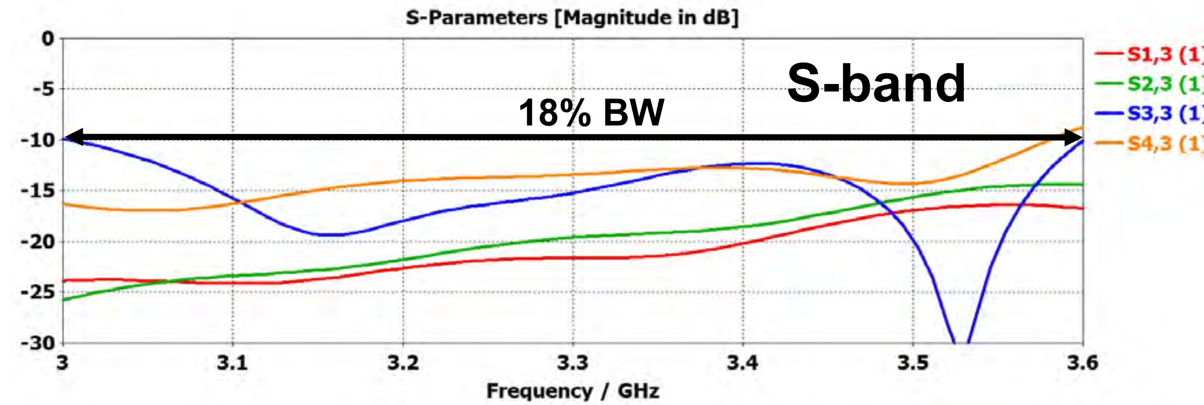
- Multiple substrates & conductive layers
- Complex geometry: concentric radiators, multiple feeds
- High cost, low volume, long lead times with traditional manufacturing

Additive Manufacturing for RF:

- ARL developing non-traditional, materials-driven approaches to manufacturing

DUAL LAYER ANTENNA GEOMETRY

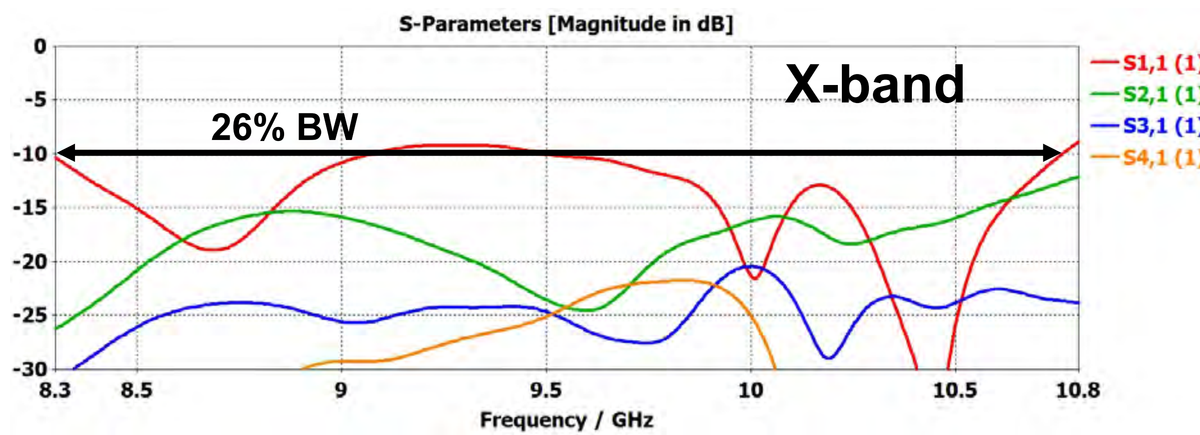
Transparent 3D View



Solid Side View

Top Duroid layer

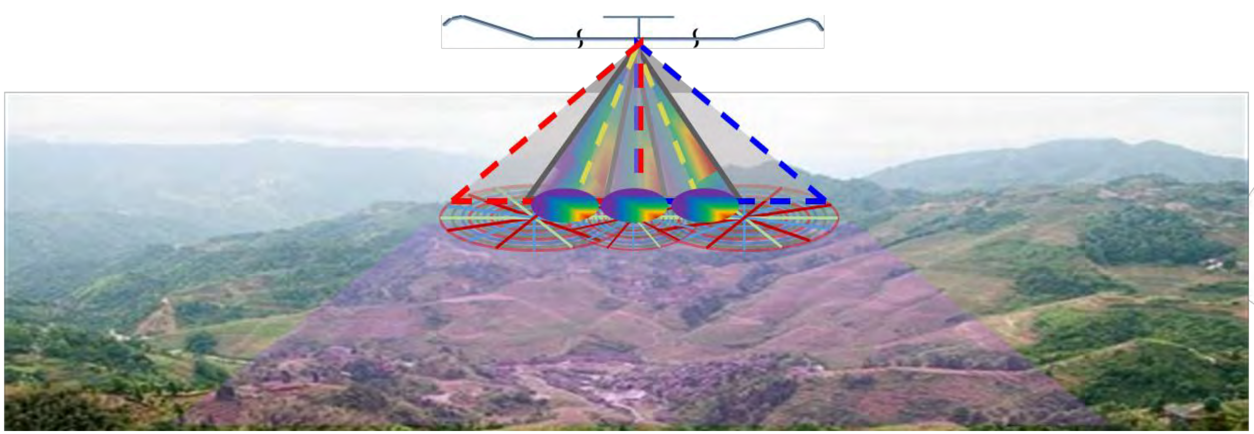
Bottom Rogers 3006 layer

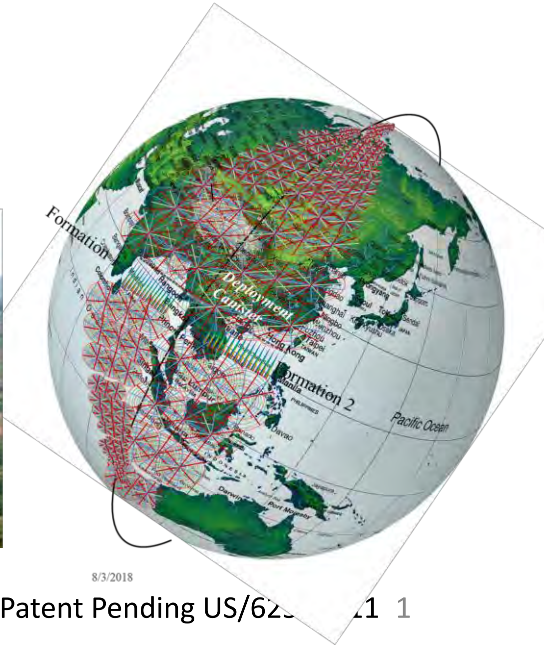


12

"Hyper-spectral, UHD imaging NANO-SAT formations or HAPS to detect, identify, geolocate and track; CBRN gases, fuel vapors and other substances

Arnold Kravitz

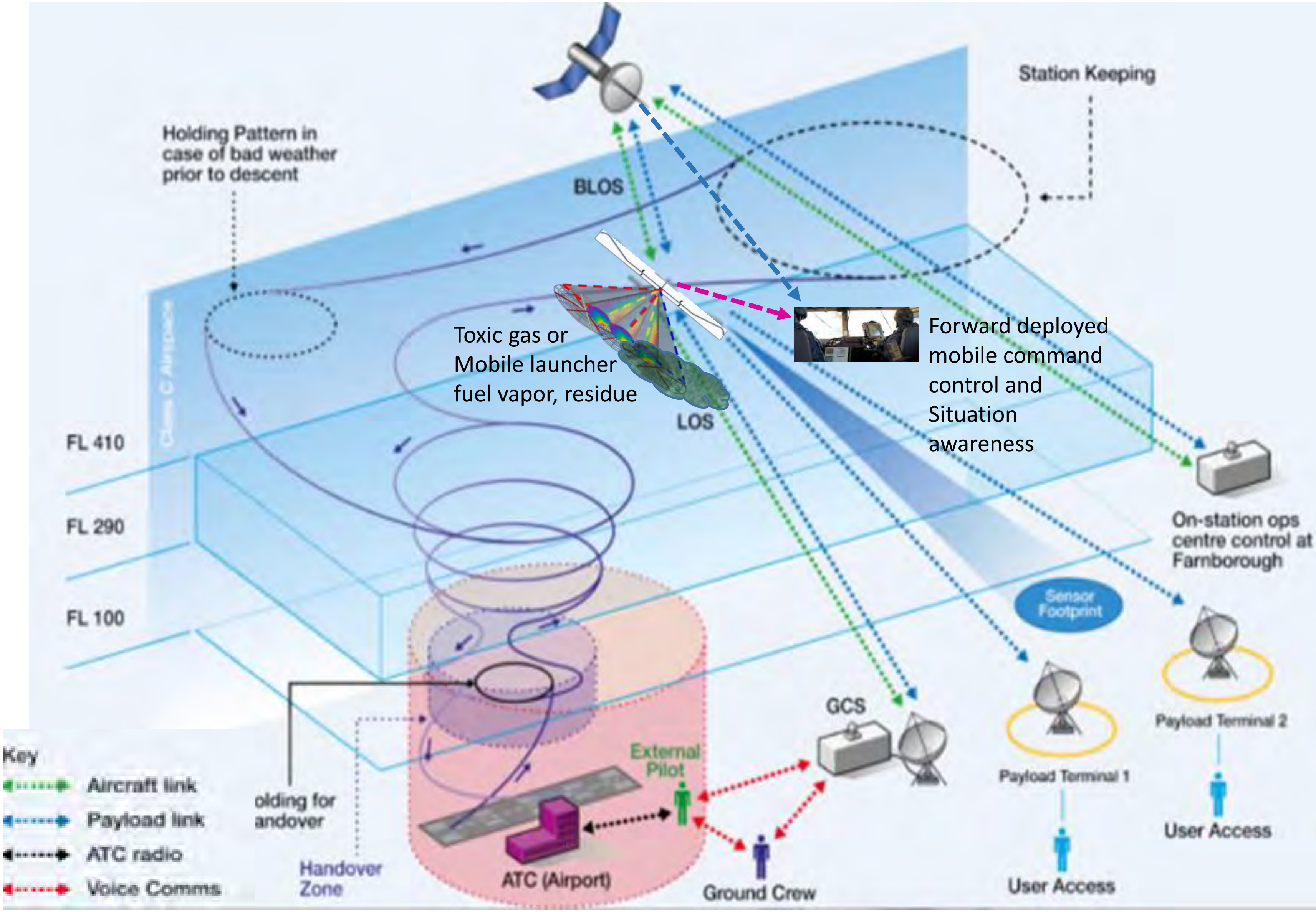




HSI and FMV Nano-sensor for UHD stereo persistent surveillance

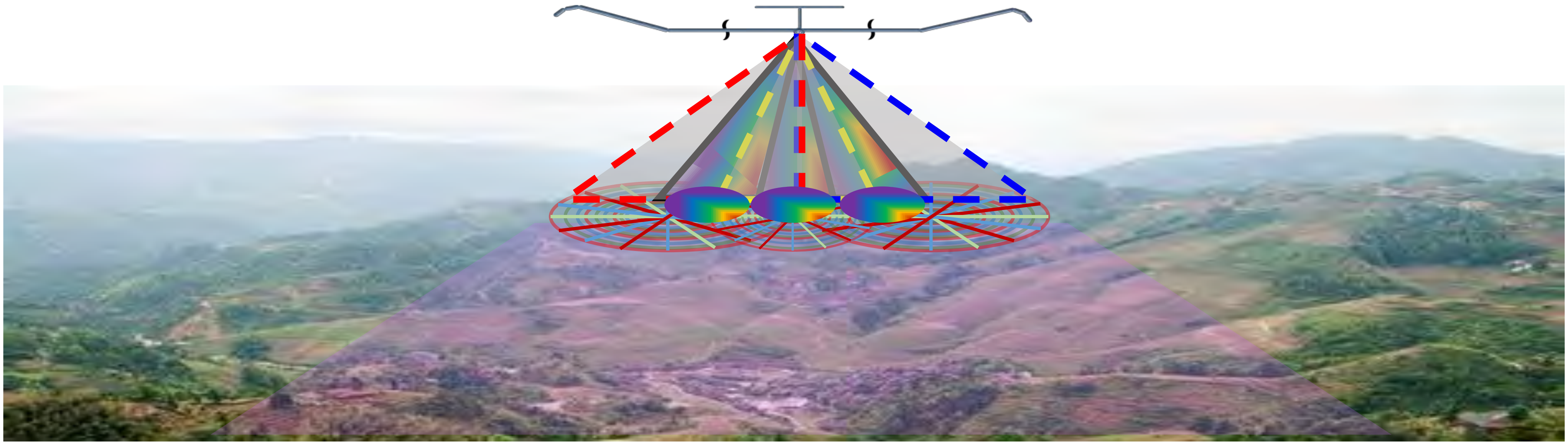
1. Detect, identify, track, and geo locate; gases vapers, and materials via hyperspectral imaging.
2. High resolution real time UHD stereo persistent surveillance co bore sighted with the Hyper spectral imager
3. Dual use as a Nanosat formation or HAPS payload

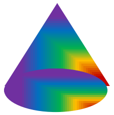
HAPS Mission Concept



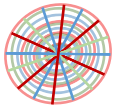
Curtesy of Airbus Defense and Space

HAPS Imaging Concept



Hyper spectral ground track 

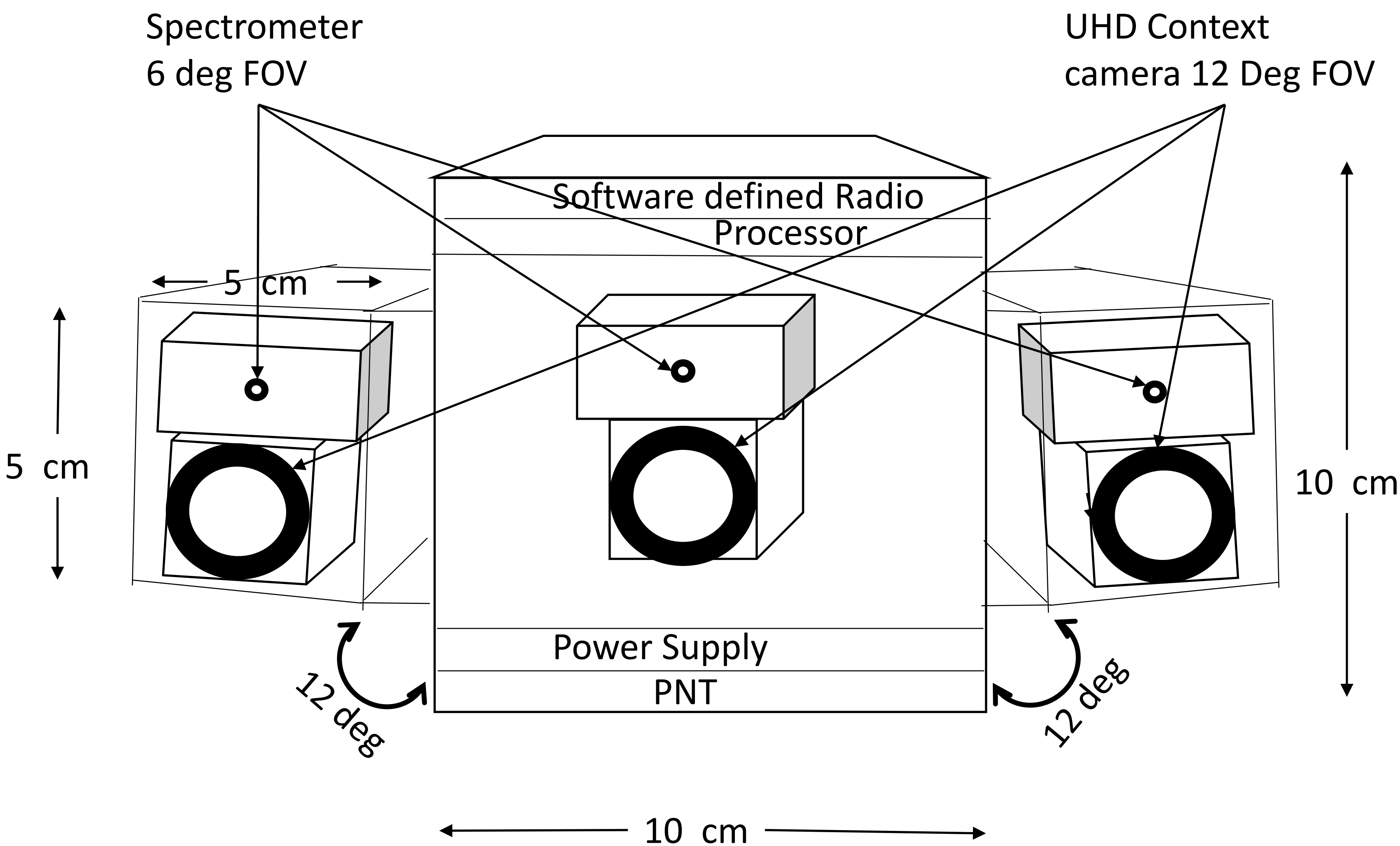
1) Hyperspectral camera ground tracks, over lap each other to form stereo imagery each other,
2) Specifics
   - Altitude 21.4 km (70,000' alt)
   - FOV 6 deg.
   - Ground swath 6.7 km
   - Resolution 744 m (via sub pixel approximation)

Stereoscopic Context ground track 

1) Context camera ground tracks, over lap each other to form stereo imagery each other,
2) Specifics
   - Altitude 21.4 km (70,000' alt)
   - FOV 12 deg.
   - Ground Swath 8.9 km
   - Resolution 29 cm (via sub pixel approximation)
   - Stereo vision via instrument 6 deg canting and 50 % overlap

HAPS Payload Major System Components

HAPS Payload Concept



Operationally responsive HAPS mission overview

- Commodity instrument commercial components
- Extended mission (months)
- Persistent Hyperspectral stereo imagery
- Full color (RGB) still and FMV (30-120 Hz frame rate) stereoscopic
  - overlapping ground swaths
  - Full coverage
  - Live video streaming RGB
  - Live stereo video streaming
- Fused Hyperspectral/ RGB imagery
- Resolution

Alt.	70,000’	60,000”	30,000”
RGB	0.29 m	0.25 m	0.049 m
HSI	744 m	638 m	319 m

- Reliability thru redundancy and graceful degradation
- Hyper spectral imagery
  - 6 degree FOV
  - Frame rate up to 30 frames / second over target
  - CMOS Spectrometer readout by cell with varying TDI intervals to maximize dynamic range.
    - Frame to frame analysis
    - If saturated readout speed is accelerated
    - If level is too low integration time is increased
- X, and ka band (2-4 Ghz or 8-12 Ghz, or 28.8 Ghz down link
- Long range vision; is commercial weather/ commodity monitoring
- Goal of a dual use payload suitable as a 1 u battery powered nanosat, HAPS Payload, or a UAV payload with component subtraction.

Video frame assembly and stereo overlap

UHD Visible band Stereo

- 12 deg FOV
- 6 deg off set camera to camera
- 10% proportionality side image to top image
- 50% overlap out side cameras (6 deg)
- 100% overlap center camera

Hyper-Spectral frame

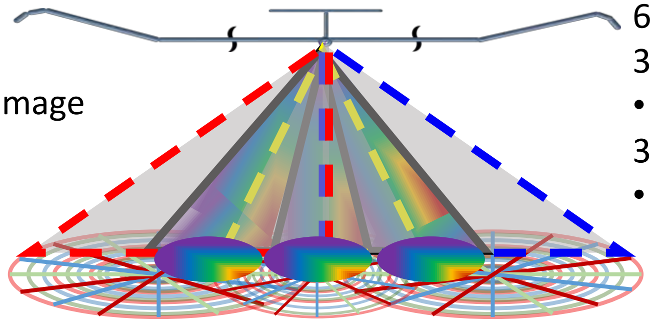
6 deg FOV

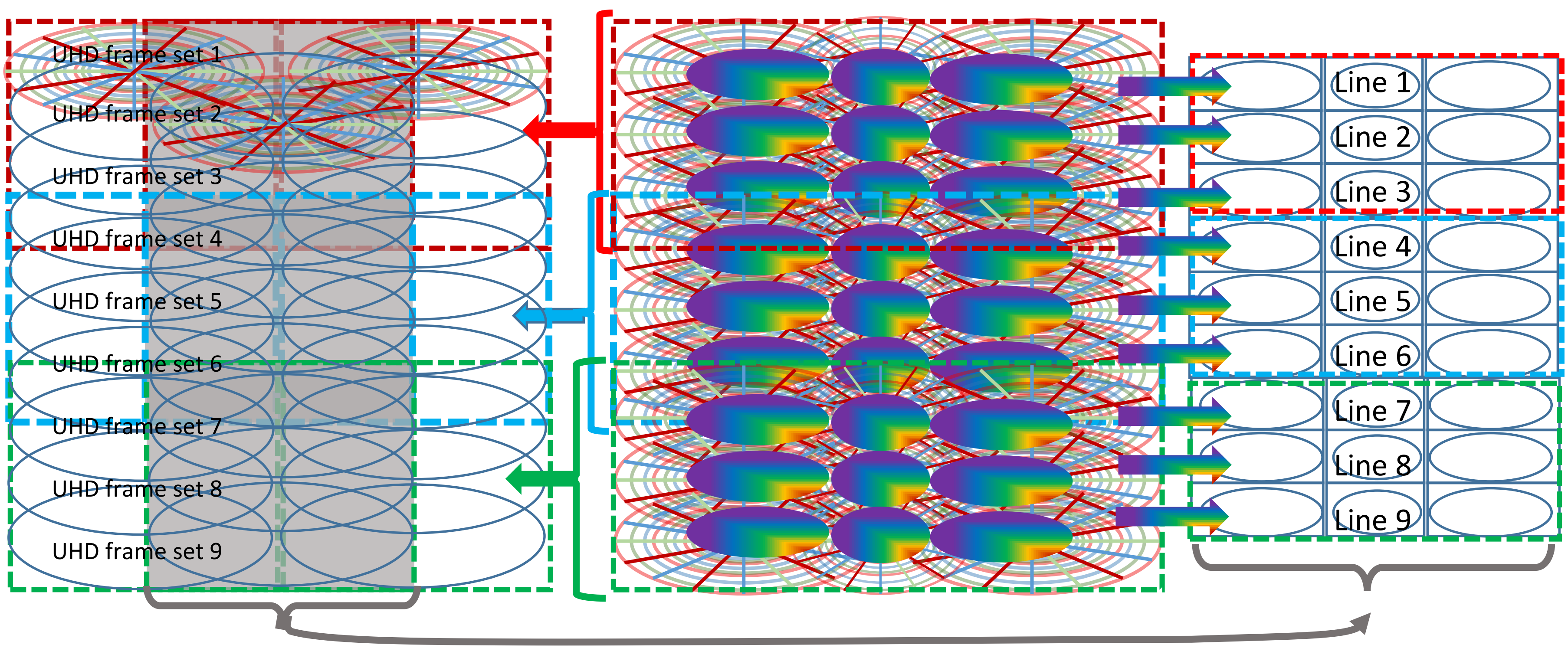
3 cameras aligned edge to edge

- 1x3 line array

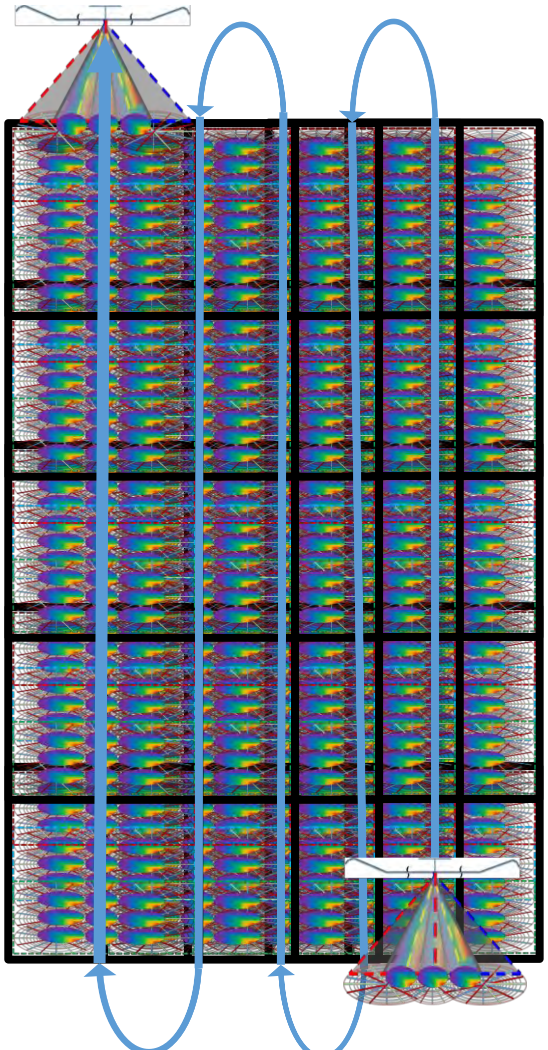
3 consecutive lines form a 3x3 array

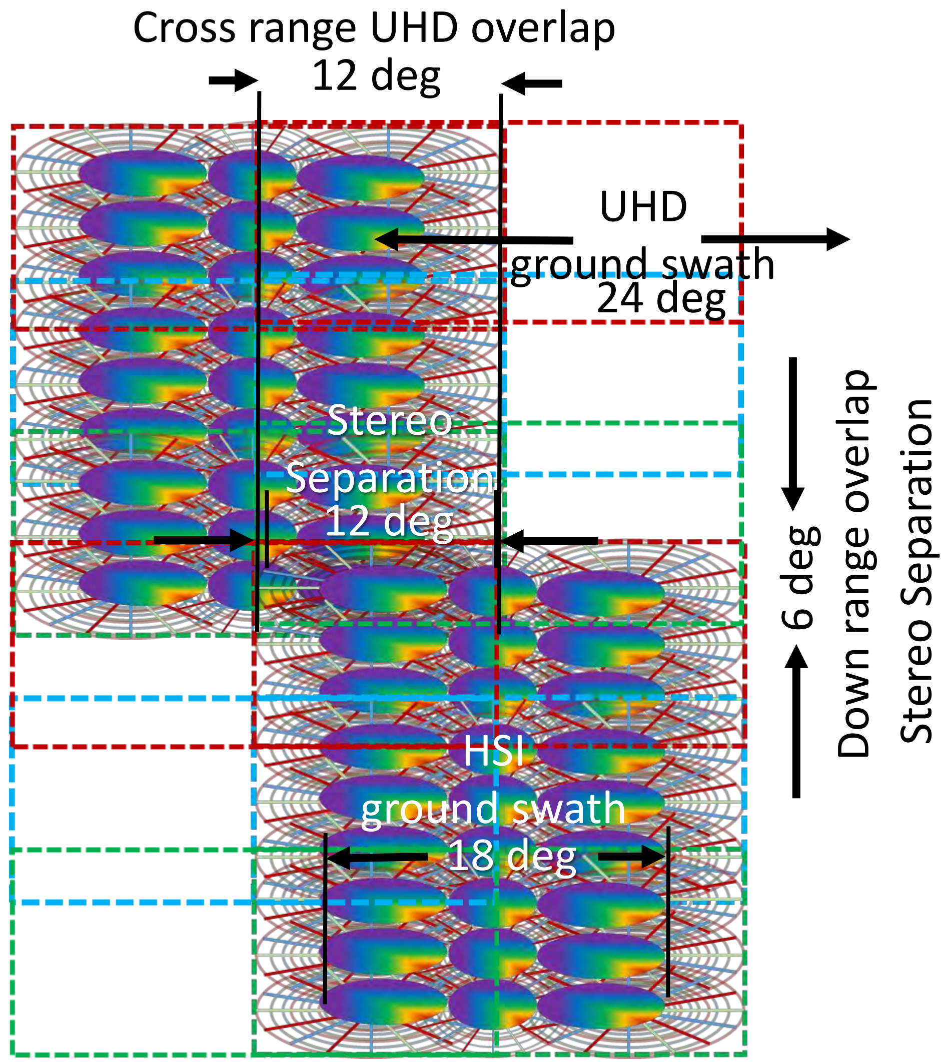
- Full area coverage
  - Frame = 3x3 array
  - Adjacent spatial frames
  - Via Flight path





Flight path, camera pointing and 2 to 1 HSI/UHD FOV ratio enables UHD stereo and line-scan gap free HSI coverage





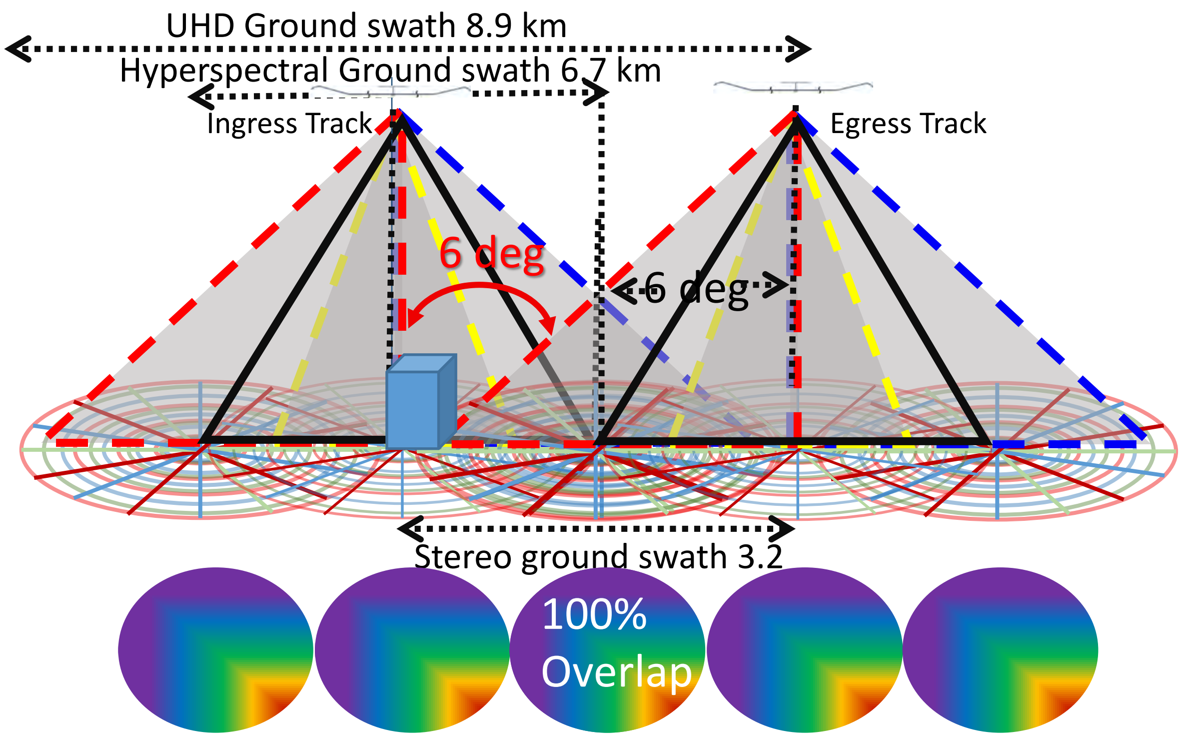
Stereo UHD Coverage

- 10.1% overlap frame to frame
- 1 outside camera image overlap via flight path

Hyperspectral imagery coverage

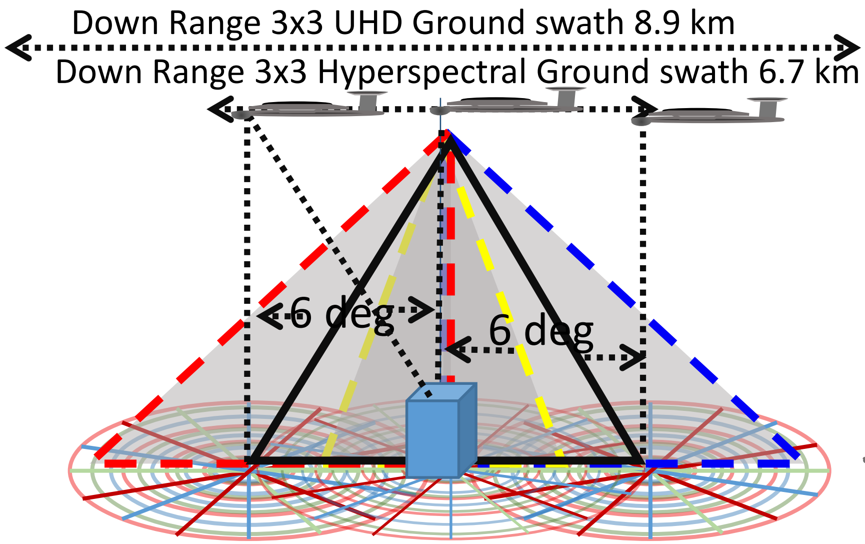
- Continuous coverage via flight path

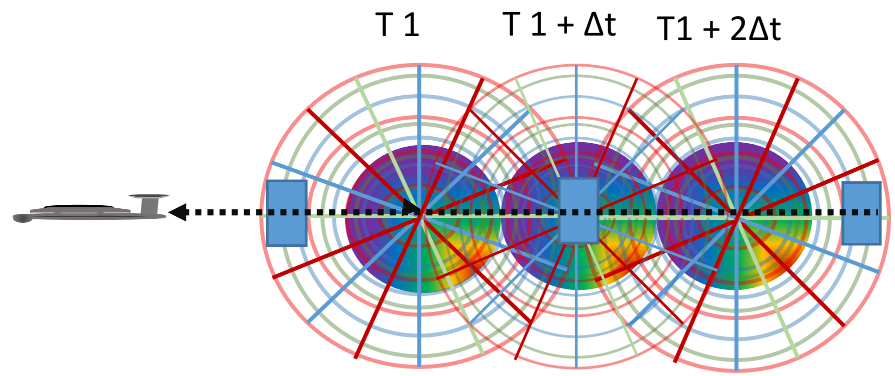
Cross range UHD 3d imagery



- Constructed from track separation angle .
- Object height perspective set by HSI overlap angle
- Object appears in different locations in multiple cameras on overlapping tracks
  a) Ingress Track 1, Center camera, location is at 0 deg
  b) Ingress Track 1, right camera, location is 6 deg left of center
  c) Egress Track 2, right camera 1 location is 6 deg right of center
- Vertical Image perspective scaling = tan(6 deg) = 10.5% true height
- Resolution = 2 x 21.3km sin(6 deg)/4072 pixels *1000/3 = 0.29 m (11 inches)

Down range UHD 3d imagery





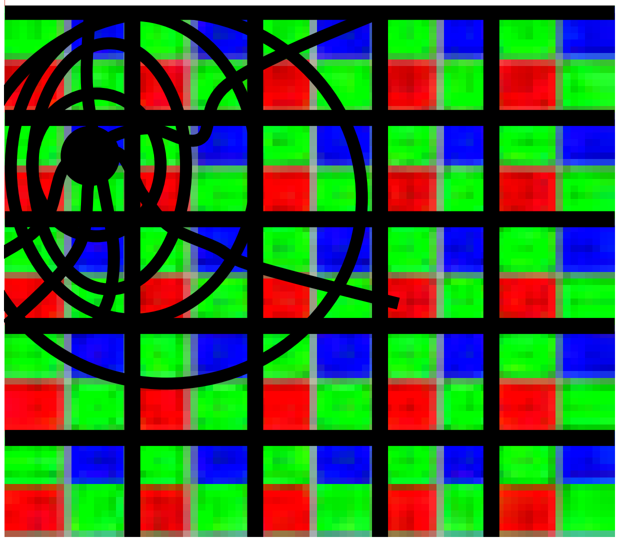
- Constructed from down range separation.
- Image Object height perspective scaling is via location geometry
- Object appears in different locations in different frames
  a) Frame 1 location is 6 deg above the top of frame
  b) Frame 2 location is center of frame
  c) Frame 3 location is 6 deg below center
  d) Vertical perspective scale = tan(6 deg) = 10.5% height
- Resolution = 2 x 21.3km sin(6 deg)/4072 pixels *1000/3
- = 0.29 m (11 inches)

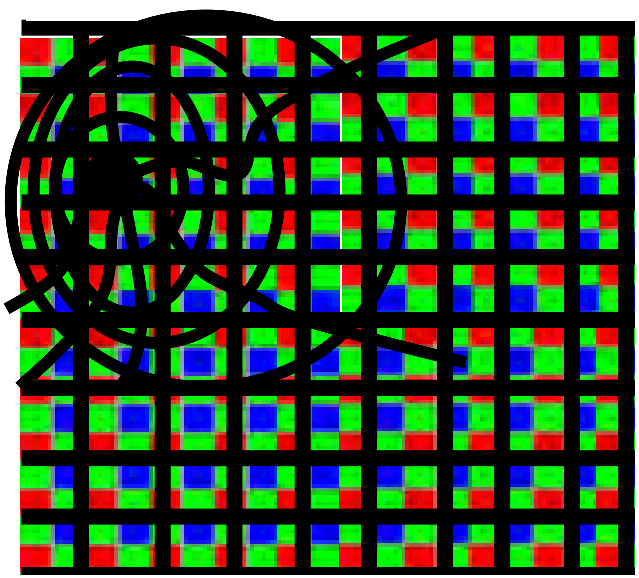
Important: The Hyperspectral frame rate for continuous coverage allows UHD Stereo Video creation same object will appear 3 times with 6 deg of separation including a top down view

HAPS Imaging Parameters

	Pixels h								4072.000	4072.000
	pixels V								3046.000	3046.000
	pixels d					1			5085.204	5085.204
	FOV(deg)					6	12			
	FOV(rad)					0.10473	0.20946			
	dif limit @F1(m)					0.000488	0.000488			
wing span (m)	alt (ft)	alt(km)	sensor spacing (m)	Single sensor Hyper spectral ground swath	3 sensor Hyper spectral ground swath (edge to edge)	Sub Pixel aprox. Hyper spectral Ground res. (m)	UHD Color Ground swath (m)	3 sensor UHD ground swath (50% sensor over lap)	Sub Pixel aprox. Ground res. METERS	Sub Pixel aprox. Ground res. INCHES
0	70000	21.336	11.25	2234.52	6703.56	744.84	4469.04	8938.08	0.29	11.533
	67500	20.574	11.25	2154.72	6464.15	718.24	4309.43	8618.86	0.28	11.12
	65000	19.812	11.25	2074.91	6224.73	691.64	4149.82	8299.64	0.27	10.71
	62500	19.05	11.25	1995.11	5985.32	665.04	3990.21	7980.43	0.26	10.30
	60000	18.288	11.25	1915.30	5745.91	638.43	3830.60	7661.21	0.25	9.89
	57500	17.526	11.25	1835.50	5506.49	611.83	3671.00	7341.99	0.24	9.47
	55000	16.764	11.25	1755.69	5267.08	585.23	3511.39	7022.77	0.23	9.06
	52500	16.002	11.25	1675.89	5027.67	558.63	3351.78	6703.56	0.22	8.65
	50000	15.24	11.25	1596.09	4788.26	532.03	3192.17	6384.34	0.21	8.24
	47500	14.478	11.25	1516.28	4548.84	505.43	3032.56	6065.12	0.20	7.83
	45000	13.716	11.25	1436.48	4309.43	478.83	2872.95	5745.91	0.19	7.41
	42500	12.954	11.25	1356.67	4070.02	452.22	2713.34	5426.69	0.18	7.00
	40000	12.192	11.25	1276.87	3830.60	425.62	2553.74	5107.47	0.17	6.59
	37500	11.43	11.25	1197.06	3591.19	399.02	2394.13	4788.26	0.16	6.18
	35000	10.668	11.25	1117.26	3351.78	372.42	2234.52	4469.04	0.15	5.77
	32500	9.906	11.25	1037.46	3112.37	345.82	2074.91	4149.82	0.14	5.35
	30000	9.144	11.25	957.65	2872.95	319.22	1915.30	3830.60	0.13	4.94
	27500	8.382	11.25	877.85	2633.54	292.62	1755.69	3511.39	0.12	4.53
	25000	7.62	11.25	798.04	2394.13	266.01	1596.09	3192.17	0.10	4.12
	22500	6.858	11.25	718.24	2154.72	239.41	1436.48	2872.95	0.09	3.71
	20000	6.096	11.25	638.43	1915.30	212.81	1276.87	2553.74	0.08	3.30
	17500	5.334	11.25	558.63	1675.89	186.21	1117.26	2234.52	0.07	2.88
	15000	4.572	11.25	478.83	1436.48	159.61	957.65	1915.30	0.06	2.47
	12500	3.81	11.25	399.02	1197.06	133.01	798.04	1596.09	0.05	2.06
	10000	3.048	11.25	319.22	957.65	106.41	638.43	1276.87	0.04	1.65
	7500	2.286	11.25	239.41	718.24	79.80	478.83	957.65	0.03	1.24
	5000	1.524	11.25	159.61	478.83	53.20	319.22	638.43	0.02	0.82
	2500	0.762	11.25	79.80	239.41	26.60	159.61	319.22	0.01	0.41
	0	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sub pixel approximation used to minimize jitter ease optical requirements and improve resolution





1. The signal as read by adjacent pixels
2. The data is curve fit
   - Sets of 3 pixels in vertical, horizontal and diagonal.
3. The result is then mapped from the 3x3 to a 9x9 and
4. Values for the higher density pixels are calculated.

Pixel intensity values

(note each pixel is a spectrometer with 200+ colors Approximation is done on the ground for each frequency.)

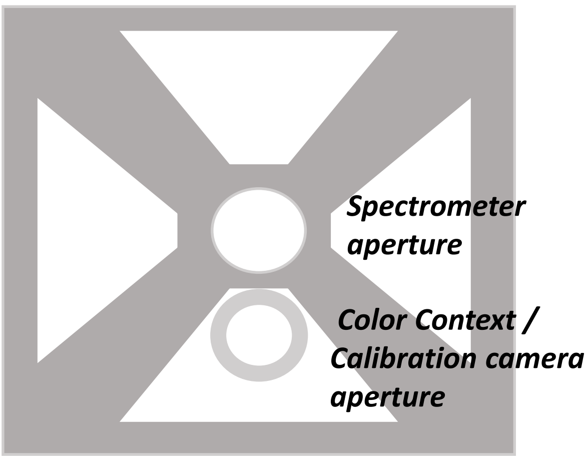
2	5	3
3	9	2
5	6	3

Pixel approximate values

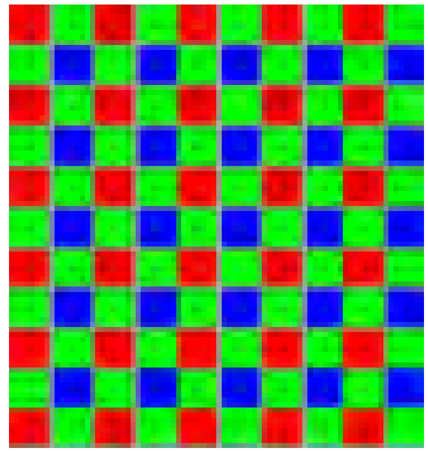
(note each pixel is a spectrometer with 200+ colors Approximation is done on the ground for each frequency.)

1	3	2	2	1				
0	4	3	2	1	1	0	0	0
1	5	4	3	2	1	0	0	0
2	9	6	3	2	1	0	0	0
2	4	5	3	2	1	0	0	0
1	2	2	3	2	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

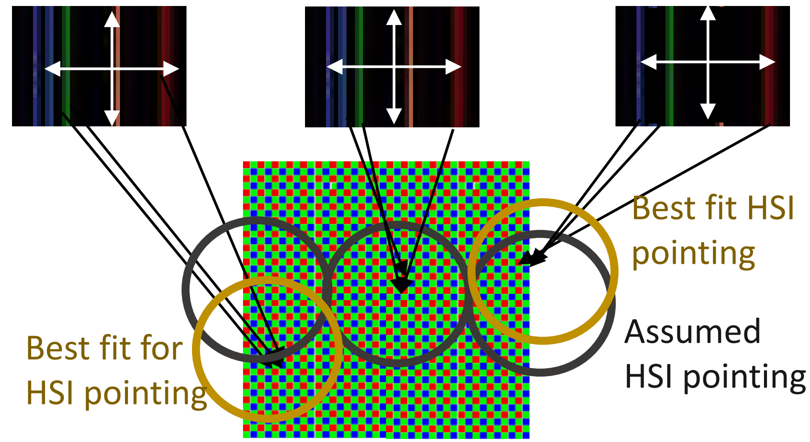
Pointing angle determination leverages the Bayer filter data to template match the HAPS instrument spectrometers to the scene to best determine the look angle and compensate for boresight misalignments, temperature variation shifting shock induced movement



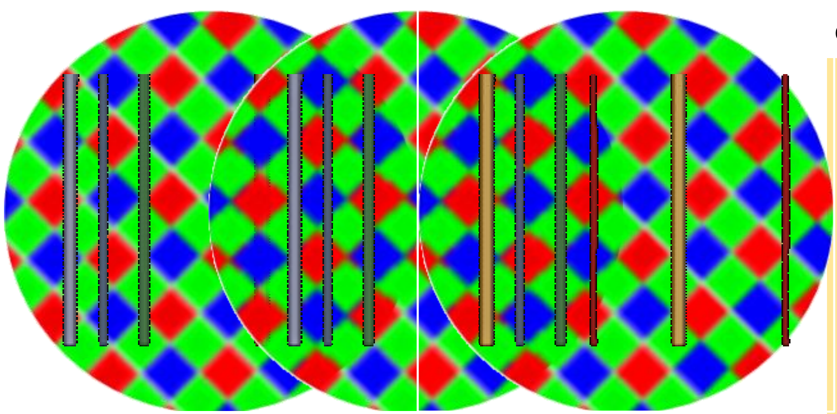
Color context camera Bayer pattern is used to provide a red green blue signature for the scene data for each geo-located ground image



The spectrometers readings are then normalized to red green and blue and the 3 sets are template matched to the nearest best fit to determine a geolocated look angle



The ground segment processing then looks at the off set and provides corrected imagery by shifting or rotating the imagery back into the desired alignment.

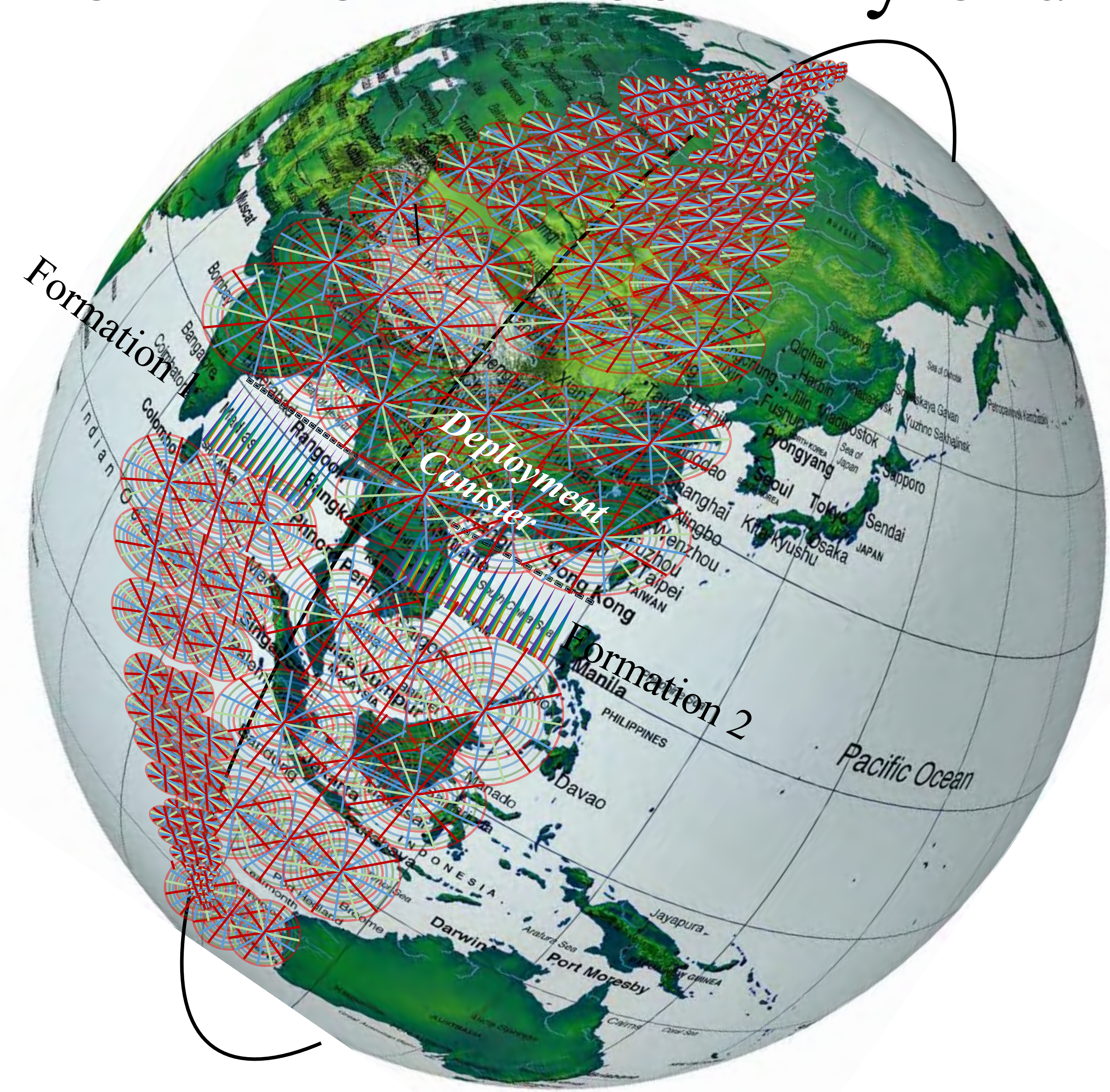


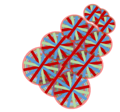
Note; all optical elements are calibrated on the ground. Pointing may be corrected via image processing on the ground or on orbit

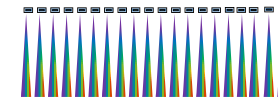
Each instrument has a PNT measurement unit the rotation rates, (clocking angle, coning angle, and centration are used to correct and align the imagery.

Data type	Image correction
• Clocking angle	a flat rotation of the imager
• Coning angle	trapezoidal stretching of the imagery
• Centration	Horizonal or vertical shifting of the imagery
• Planar Translation	flat scaling of the imagery

Formation Nanosat Payload Concept



Context camera ground track 

Hyper spectral ground track 

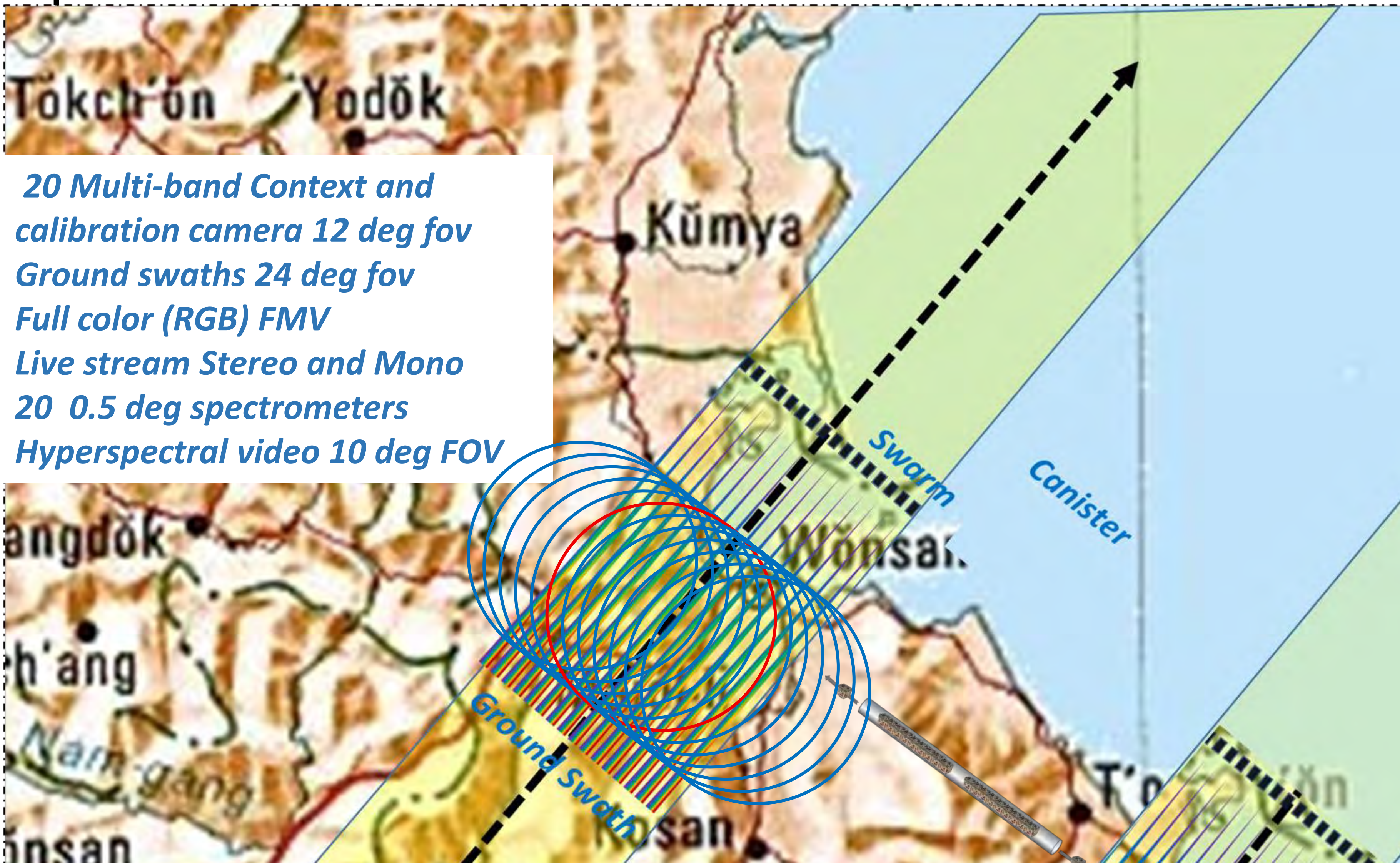
Note;

1) The context camera ground tracks, abut each other, orbit to orbit at max altitude and over lap as orbit decays.
2) Specifics

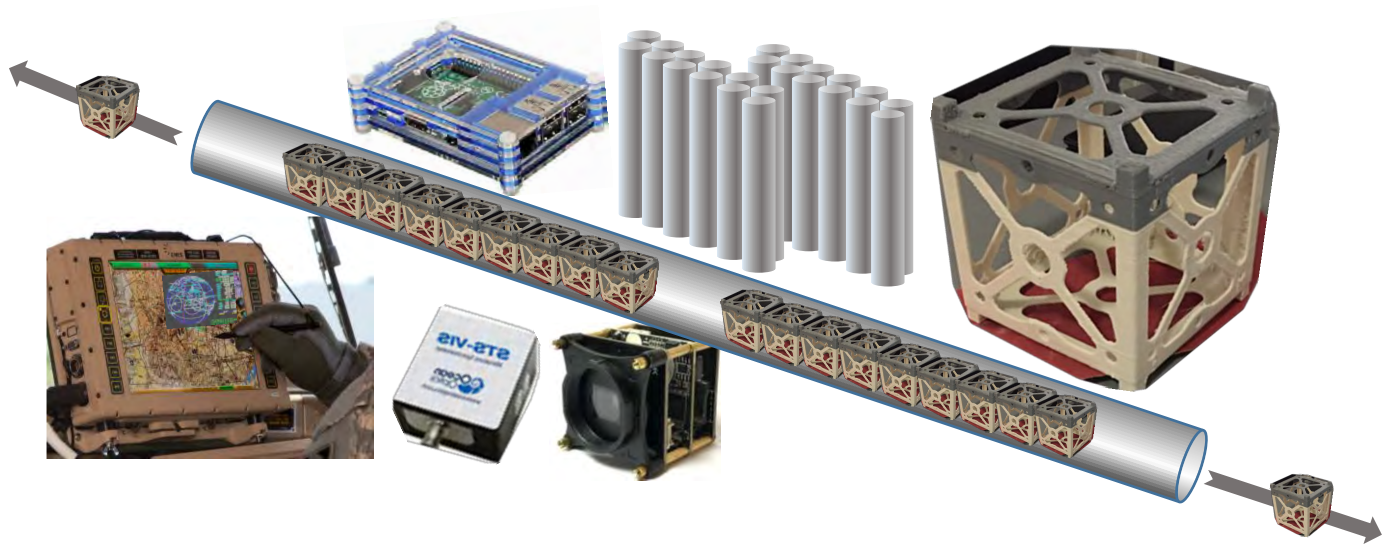
- Orbit- 274 km polar
- 16 orbits / day
- Period -1.5 hrs,
- UHD Context camera
  - FOV 12 deg.
  - Resolution 4.7 m
- Stereo vision via cube to cube spacing
  - 85.8Km ground swath
    - 20 Nanosat formation
  - 6 deg stereo separation
    - 1st to 8th and 10 nanosat
    - 28.6 km separation
  - Vertical scaling =10.5%

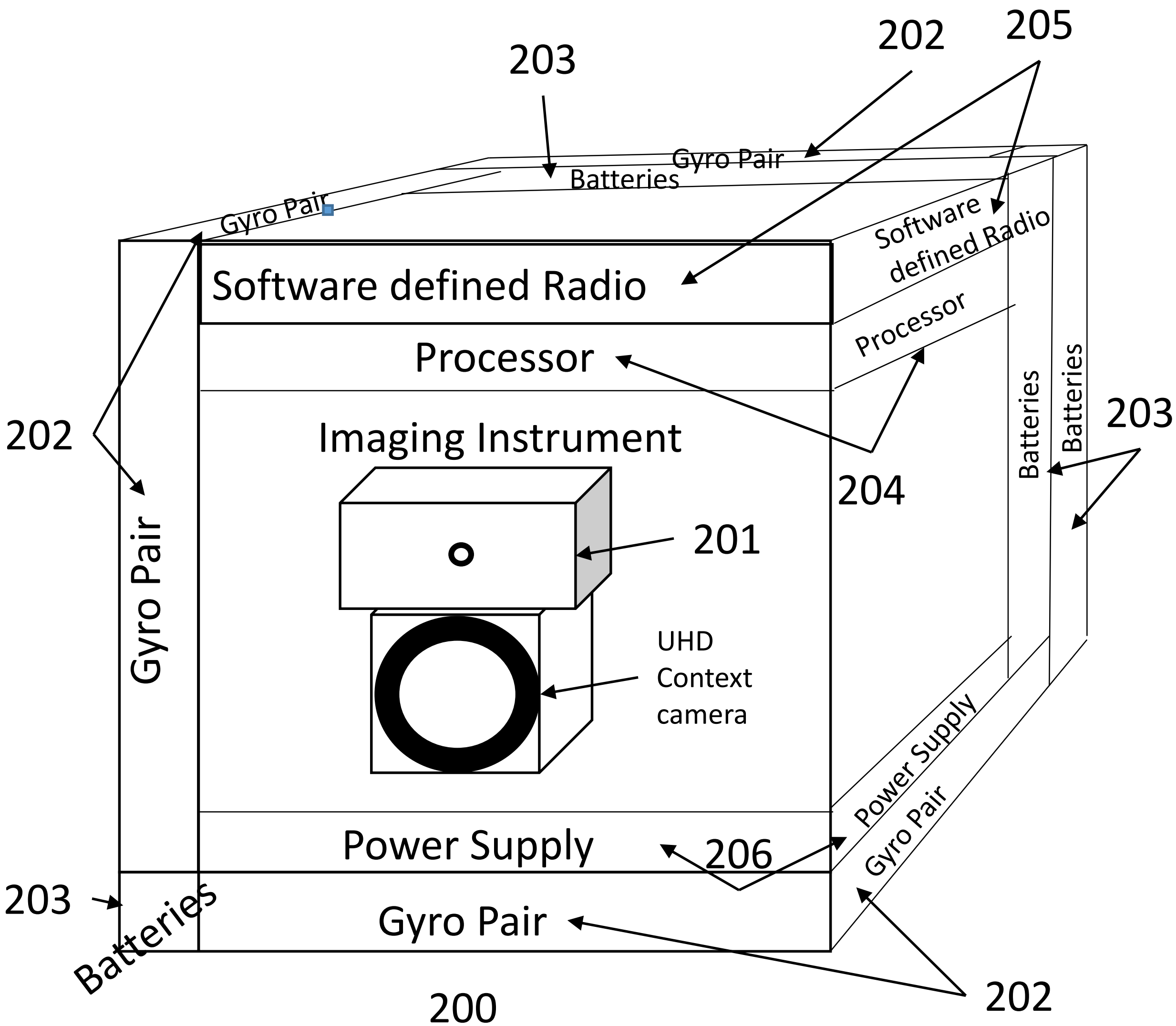
Spectrometer Swarm - Ground Swath

20 Multi-band Context and calibration camera 12 deg fov
Ground swaths 24 deg fov
Full color (RGB) FMV
Live stream Stereo and Mono
20 0.5 deg spectrometers
Hyperspectral video 10 deg FOV



Major System Components





Cube Sat

A **CubeSat** (U-class spacecraft) is a type of miniaturized satellite for space research made up of multiples of 10×10×11.35 cm cubic units, has a mass of no more than 1.33 kilograms per unit, and often see the use of commercial off-the-shelf (COTS) components for its electronics and structure

NANOSAT momentum balanced deployment

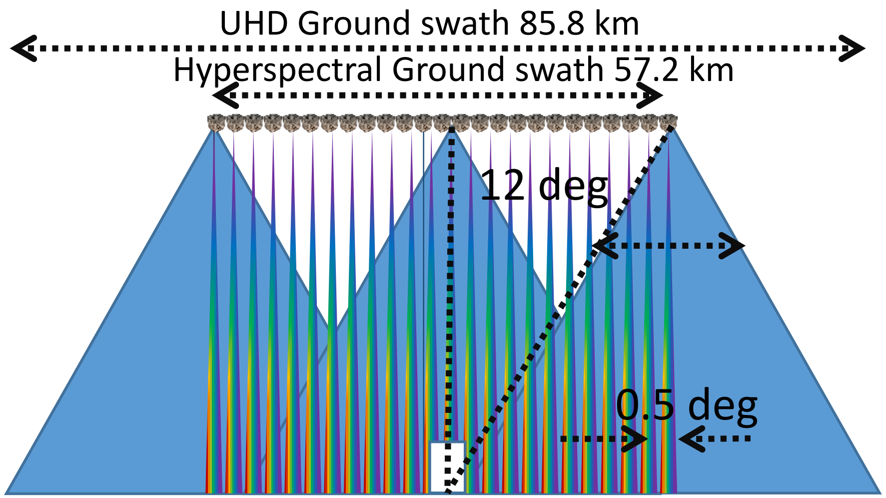
Deployed NANOSATS (quantity 20)

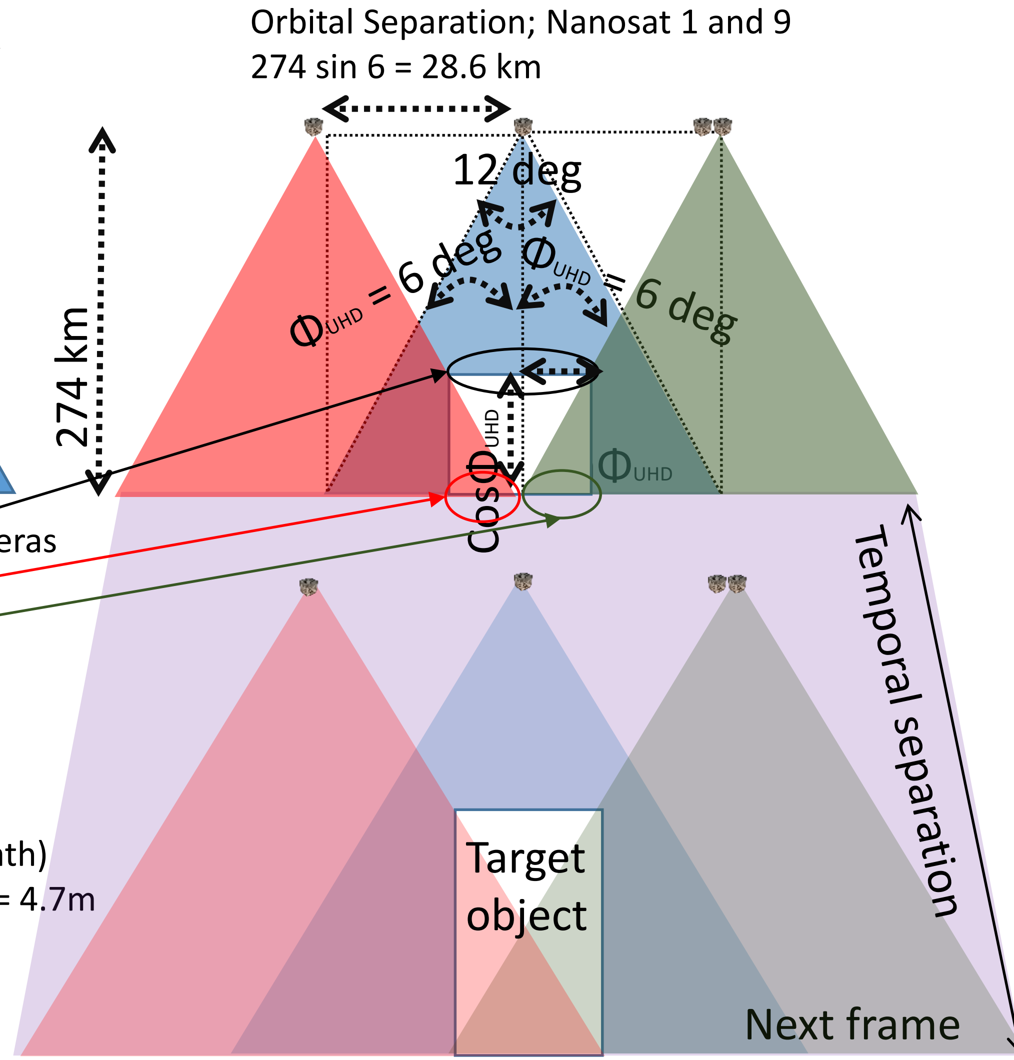
Deployed NANOSATS (quantity 20)

Operationally responsive Formation Nanosat

- Commodity Nano Sat (multi utility mission)
- 4 week mission
- Near earth orbit 274 Km to 80Km?
- Commercial components
- Low cost commercial launch
- Hyperspectral imagery 2/ per day
- Full color (RGB) still and FMV (30 Hz) imagery
    - 22 deg swath, 4.7m resolution
    - full gap free slightly overlapping ground swaths
    - Full coverage every 16 orbits
    - Live video streaming RGB 3d imagery
- Fused Hyperspectral/ RGB imagery
- Reliability thru redundancy and graceful degradation
- Hyper spectral imagery
    - 1/8 to ½ degree FOV for 200m to 800m resolution from 274KM
    - 10 frames over target per orbit at 30 hz
- Mono and Stereo Mono full color full motion video
    - 12 deg FOV (gap free swath to swath overlapping orbital coverage.
    - Full earth coverage every 24hrs
- X, and ka band (2-4 Ghz or 8-12 Ghz, or 28.8 Ghz down link
- Long range vision; is commercial weather/ commodity monitoring

UHD Stereo and 3d imagery is constructed from cross range separation and down range temporal displacement. 3d Scaling is determined from orbital geometry





- Object appears in different locations in multiple cameras
  - a) Center camera 9, and 10,
  - b) Extreme right camera 1
  - c) Extreme left in camera 20
- Vertical scaling % = tan(6 deg) = 10.5%
  - a) Alt,
  - b) UHD-FOV,
  - c) Camera separation (hyperspectral ground swath)
- Resolution = 2 x 274 sin(6 deg)/4072 pixels *1000/3 = 4.7m
- 3d imagery is constructed using the video motion to capture the down range dimension
- ***Note: Nanosats form a Single hyperspectral array preventing stereo hyperspectral imagery***

Orbital Parameters

- Target revisit with a 1/8th degree FOV and 198 m (sub pixel) ground resolution at 274 km orbit
- Target revisit with a 1/4th degree FOV and 396 m (sub pixel) ground resolution at 274 km orbit
- Target revisit with a 1/2th degree FOV and 791 m (sub pixel) ground resolution at 274 km orbit

Alt Km4 7.82 km and	V (Km/ sec)	T hr	T min	T Sec	Pixel Ground resolution (m) with1/3 pixel, sub pixel approximation (diameterof spot)			Gound swath width(km)			
					20	20	20	20	20	20	Week 0
					0.125	0.25	0.5	0.125	0.25	0.5	Day 0
								2.5	5	10	Orbit 0
300	7.73	1	30	31.18	0.218	0.436	0.873	13.090	26.18	52.36	0
298	7.73	1	30	28.74	0.217	0.433	0.867	13.003	26.01	52.01	0
296	7.73	1	30	26.30	0.215	0.431	0.861	12.915	25.83	51.66	0
294	7.73	1	30	23.86	0.214	0.428	0.855	12.828	25.66	51.31	0
292	7.73	1	30	21	0.212	0.425	0.849	12.741	25.48	50.96	0
290	7.73	1	30	19	0.211	0.422	0.844	12.654	25.31	50.61	0
288	7.73	1	30	16.55	0.209	0.419	0.838	12.566	25.13	50.27	0
286	7.73	1	30	14.11	0.208	0.416	0.832	12.479	24.96	49.92	0
284	7.74	1	30	11.67	0.207	0.413	0.826	12.392	24.78	49.57	0
282	7.74	1	30	9.24	0.205	0.410	0.820	12.305	24.61	49.22	0
280	7.74	1	30	6.80	0.204	0.407	0.814	12.217	24.43	48.87	0
278	7.74	1	30	4.36	0.202	0.404	0.809	12.130	24.26	48.52	0
276	7.74	1	30	1.93	0.201	0.401	0.803	12.043	24.09	48.17	0
274	7.74	1	29	59.49	0.199	0.399	0.797	11.956	23.91	47.82	0
272	7.74	1	29	57.06	0.198	0.396	0.791	11.868	23.74	47.47	0
270	7.74	1	29	54.62	0.196	0.393	0.785	11.781	23.56	47.12	0
268	7.74	1	29	52.19	0.195	0.390	0.780	11.694	23.39	46.77	0
266	7.75	1	29	49.76	0.193	0.387	0.774	11.606	23.21	46.43	0
264	7.75	1	29	47.32	0.192	0.384	0.768	11.519	23.04	46.08	0
262	7.75	1	29	44.89	0.191	0.381	0.762	11.432	22.86	45.73	0
260	7.75	1	29	42.46	0.189	0.378	0.756	11.345	22.69	45.38	0
258	7.75	1	29	40.02	0.188	0.375	0.750	11.257	22.51	45.03	0
256	7.75	1	29	37.59	0.186	0.372	0.745	11.170	22.34	44.68	0
254	7.75	1	29	35.16	0.185	0.369	0.739	11.083	22.17	44.33	0
252	7.75	1	29	32.73	0.183	0.367	0.733	10.996	21.99	43.98	0
250	7.75	1	29	30.30	0.182	0.364	0.727	10.908	21.82	43.63	0
248	7.76	1	29	27.87	0.180	0.361	0.721	10.821	21.64	43.28	0
246	7.76	1	29	25.44	0.179	0.358	0.716	10.734	21.47	42.94	0
244	7.76	1	29	23.01	0.177	0.355	0.710	10.647	21.29	42.59	0
242	7.76	1	29	20.58	0.176	0.352	0.704	10.559	21.12	42.24	0
240	7.76	1	29	18.15	0.175	0.349	0.698	10.472	20.94	41.89	0

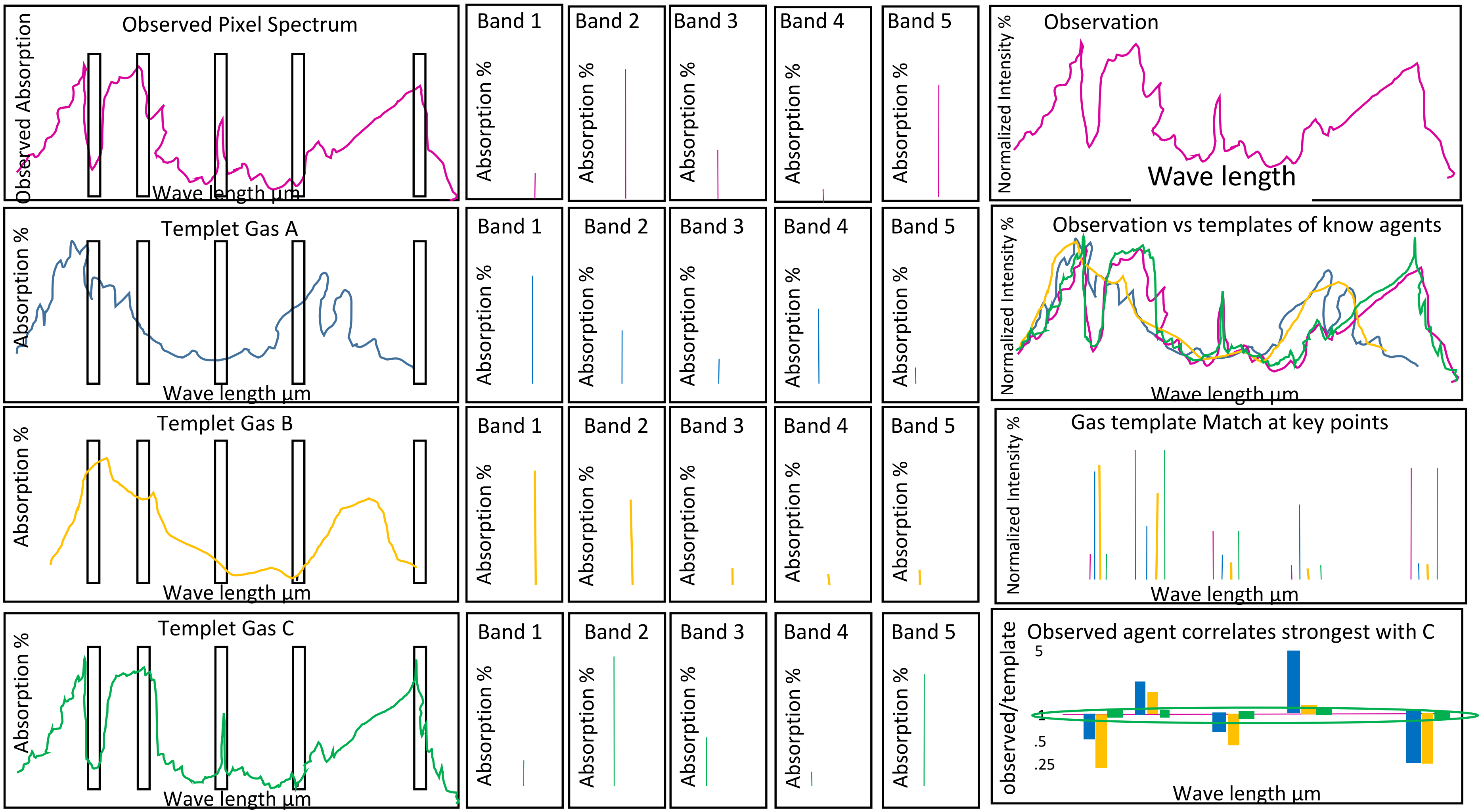
Alt													
Week							1						
Day	1	2	3	4	5	6	7	8	9	10	11	12	13
Orbit	16	32	48	64	80	96	112	128	144	160	176	192	208
300	231.40	462.80	694.20	925.60	1157.00	1388.40	1619.80	1851.20	2082.60	2314.00	2545.39	2776.79	3008.19
298	213.29	426.59	639.88	853.18	1066.47	1279.76	1493.06	1706.35	1919.65	2132.94	2346.24	2559.53	2772.82
296	195.19	390.38	585.57	780.77	975.96	1171.15	1366.34	1561.53	1756.72	1951.92	2147.11	2342.30	2537.49
294	177.09	354.18	531.27	708.37	885.46	1062.55	1239.64	1416.73	1593.82	1770.92	1948.01	2125.10	2302.19
292	158.99	317.99	476.98	635.98	794.97	953.97	1112.96	1271.95	1430.95	1589.94	1748.94	1907.93	2066.93
290	140.90	281.80	422.70	563.60	704.50	845.40	986.30	1127.20	1268.10	1409.00	1549.90	1690.80	1831.70
288	122.81	245.62	368.42	491.23	614.04	736.85	859.66	982.46	1105.27	1228.08	1350.89	1473.70	1596.50
286	104.72	209.44	314.16	418.88	523.59	628.31	733.03	837.75	942.47	1047.19	1151.91	1256.63	1361.35
284	86.63	173.27	259.90	346.53	433.16	519.80	606.43	693.06	779.69	866.33	952.96	1039.59	1126.22
282	68.55	137.10	205.65	274.20	342.74	411.29	479.84	548.39	616.94	685.49	754.04	822.59	891.14
280	50.47	100.94	151.40	201.87	252.34	302.81	353.28	403.74	454.21	504.68	555.15	605.62	656.08
278	32.39	64.78	97.17	129.56	161.95	194.34	226.73	259.12	291.51	323.90	356.29	388.68	421.07
276	14.31	28.63	42.94	57.26	71.57	85.89	100.20	114.51	128.83	143.14	157.46	171.77	186.09
274	40071.24	40067.48	40063.72	40059.97	40056.21	40052.45	40048.69	40044.93	40041.17	40037.41	40033.66	40029.90	40026.14
272	40053.17	40031.34	40009.51	39987.69	39965.86	39944.03	39922.20	39900.37	39878.54	39856.71	39834.89	39813.06	39791.23
270	40035.10	39995.21	39955.31	39915.42	39875.52	39835.62	39795.73	39755.83	39715.94	39676.04	39636.14	39596.25	39556.35
268	40017.04	39959.08	39901.12	39843.16	39785.20	39727.24	39669.28	39611.31	39553.35	39495.39	39437.43	39379.47	39321.51
266	39998.98	39922.95	39846.93	39770.91	39694.89	39618.86	39542.84	39466.82	39390.80	39314.77	39238.75	39162.73	39086.71
264	39980.92	39886.84	39792.75	39698.67	39604.59	39510.51	39416.43	39322.35	39228.26	39134.18	39040.10	38946.02	38851.94
262	39962.86	39850.72	39738.59	39626.45	39514.31	39402.17	39290.03	39177.89	39065.76	38953.62	38841.48	38729.34	38617.20
260	39944.81	39814.62	39684.42	39554.23	39424.04	39293.85	39163.66	39033.46	38903.27	38773.08	38642.89	38512.70	38382.50
258	39926.76	39778.51	39630.27	39482.03	39333.78	39185.54	39037.30	38889.06	38740.81	38592.57	38444.33	38296.08	38147.84
256	39908.71	39742.42	39576.13	39409.83	39243.54	39077.25	38910.96	38744.67	38578.38	38412.09	38245.79	38079.50	37913.21
254	39890.66	39706.33	39521.99	39337.65	39153.31	38968.98	38784.64	38600.30	38415.97	38231.63	38047.29	37862.96	37678.62
252	39872.62	39670.24	39467.86	39265.48	39063.10	38860.72	38658.34	38455.96	38253.58	38051.20	37848.82	37646.44	37444.06
250	39854.58	39634.16	39413.74	39193.32	38972.90	38752.48	38532.06	38311.64	38091.22	37870.80	37650.38	37429.96	37209.54
248	39836.54	39598.08	39359.63	39121.17	38882.71	38644.25	38405.80	38167.34	37928.88	37690.42	37451.97	37213.51	36975.05
246	39818.51	39562.02	39305.52	39049.03	38792.54	38536.05	38279.55	38023.06	37766.57	37510.08	37253.59	36997.09	36740.60
244	39800.48	39525.95	39251.43	38976.90	38702.38	38427.85	38153.33	37878.81	37604.28	37329.76	37055.23	36780.71	36506.18
242	39782.45	39489.89	39197.34	38904.79	38612.23	38319.68	38027.13	37734.57	37442.02	37149.46	36856.91	36564.36	36271.80
240	39764.42	39453.84	39143.26	38832.68	38522.10	38211.52	37900.94	37590.36	37279.78	36969.20	36658.62	36348.04	36037.46

Alt													
Week	2							3					
Day	14	15	16	17	18	19	20	21	22	23	24	25	26
Orbit	224	240	256	272	288	304	320	336	352	368	384	400	416
300	3239.59	3470.99	3702.39	3933.79	4165.19	4396.59	4627.99	4859.39	5090.79	5322.19	5553.59	5784.99	6016.39
298	2986.12	3199.41	3412.71	3626.00	3839.29	4052.59	4265.88	4479.18	4692.47	4905.77	5119.06	5332.35	5545.65
296	2732.68	2927.87	3123.06	3318.26	3513.45	3708.64	3903.83	4099.02	4294.21	4489.40	4684.60	4879.79	5074.98
294	2479.28	2656.37	2833.47	3010.56	3187.65	3364.74	3541.83	3718.92	3896.01	4073.11	4250.20	4427.29	4604.38
292	2225.92	2384.92	2543.91	2702.90	2861.90	3020.89	3179.89	3338.88	3497.88	3656.87	3815.86	3974.86	4133.85
290	1972.60	2113.50	2254.40	2395.30	2536.20	2677.10	2818.00	2958.90	3099.80	3240.70	3381.60	3522.50	3663.40
288	1719.31	1842.12	1964.93	2087.74	2210.54	2333.35	2456.16	2578.97	2701.78	2824.58	2947.39	3070.20	3193.01
286	1466.07	1570.78	1675.50	1780.22	1884.94	1989.66	2094.38	2199.10	2303.82	2408.54	2513.25	2617.97	2722.69
284	1212.86	1299.49	1386.12	1472.75	1559.39	1646.02	1732.65	1819.28	1905.92	1992.55	2079.18	2165.81	2252.45
282	959.68	1028.23	1096.78	1165.33	1233.88	1302.43	1370.98	1439.53	1508.08	1576.63	1645.17	1713.72	1782.27
280	706.55	757.02	807.49	857.96	908.42	958.89	1009.36	1059.83	1110.30	1160.76	1211.23	1261.70	1312.17
278	453.46	485.85	518.24	550.63	583.02	615.41	647.80	680.18	712.57	744.96	777.35	809.74	842.13
276	200.40	214.71	229.03	243.34	257.66	271.97	286.28	300.60	314.91	329.23	343.54	357.86	372.17
274	40022.38	40018.62	40014.86	40011.10	40007.35	40003.59	39999.83	39996.07	39992.31	39988.55	39984.79	39981.04	39977.28
272	39769.40	39747.57	39725.74	39703.91	39682.08	39660.26	39638.43	39616.60	39594.77	39572.94	39551.11	39529.28	39507.46
270	39516.46	39476.56	39436.66	39396.77	39356.87	39316.98	39277.08	39237.18	39197.29	39157.39	39117.50	39077.60	39037.70
268	39263.55	39205.59	39147.63	39089.67	39031.71	38973.75	38915.79	38857.83	38799.87	38741.91	38683.94	38625.98	38568.02
266	39010.68	38934.66	38858.64	38782.62	38706.59	38630.57	38554.55	38478.53	38402.50	38326.48	38250.46	38174.44	38098.41
264	38757.86	38663.77	38569.69	38475.61	38381.53	38287.45	38193.36	38099.28	38005.20	37911.12	37817.04	37722.96	37628.87
262	38505.06	38392.93	38280.79	38168.65	38056.51	37944.37	37832.23	37720.10	37607.96	37495.82	37383.68	37271.54	37159.41
260	38252.31	38122.12	37991.93	37861.74	37731.54	37601.35	37471.16	37340.97	37210.78	37080.58	36950.39	36820.20	36690.01
258	37999.60	37851.35	37703.11	37554.87	37406.62	37258.38	37110.14	36961.90	36813.65	36665.41	36517.17	36368.92	36220.68
256	37746.92	37580.63	37414.34	37248.05	37081.75	36915.46	36749.17	36582.88	36416.59	36250.30	36084.01	35917.71	35751.42
254	37494.28	37309.94	37125.61	36941.27	36756.93	36572.60	36388.26	36203.92	36019.59	35835.25	35650.91	35466.57	35282.24
252	37241.68	37039.30	36836.92	36634.54	36432.16	36229.78	36027.40	35825.02	35622.64	35420.26	35217.88	35015.50	34813.12
250	36989.12	36768.70	36548.28	36327.86	36107.44	35887.02	35666.60	35446.18	35225.76	35005.34	34784.92	34564.50	34344.08
248	36736.59	36498.14	36259.68	36021.22	35782.76	35544.31	35305.85	35067.39	34828.93	34590.48	34352.02	34113.56	33875.10
246	36484.11	36227.62	35971.12	35714.63	35458.14	35201.65	34945.16	34688.66	34432.17	34175.68	33919.19	33662.69	33406.20
244	36231.66	35957.14	35682.61	35408.09	35133.56	34859.04	34584.52	34309.99	34035.47	33760.94	33486.42	33211.89	32937.37
242	35979.25	35686.70	35394.14	35101.59	34809.04	34516.48	34223.93	33931.38	33638.82	33346.27	33053.72	32761.16	32468.61
240	35726.88	35416.30	35105.72	34795.14	34484.56	34173.98	33863.40	33552.82	33242.24	32931.66	32621.08	32310.50	31999.92

274 Km orbit
1:29:57 sec period (16 orbit/24hr day)
Hyper spectral pixel ground spot 2.37 KM @ ½ FOV deg
Spectrometer resolution 791m (1/3 pixel resolution via processing)
Hyperspectral Time over target 2.37km/7.47Km/sec =.32 sec
Frame rate =30 hz
frames on target 30/sec x 0.32 sec= 10

UHD
Two 20 pixel formations per canister
UHD ground swath at 12 Deg per camera (4.7m resolution)
Formation ground swath width 10 X 2.37+ 12 x Π/180 x 274= 47.6 km
Canister scan width (2 formations) = 85.2 km + separation

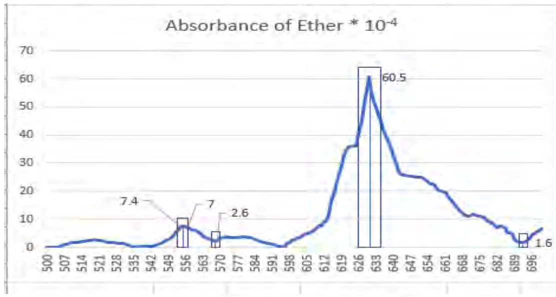
Template matching across multiple bands is used to identify observed gases

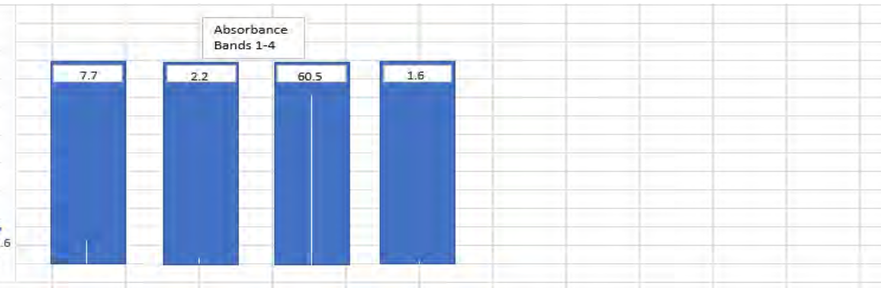


Sequential Algorithms

Observe

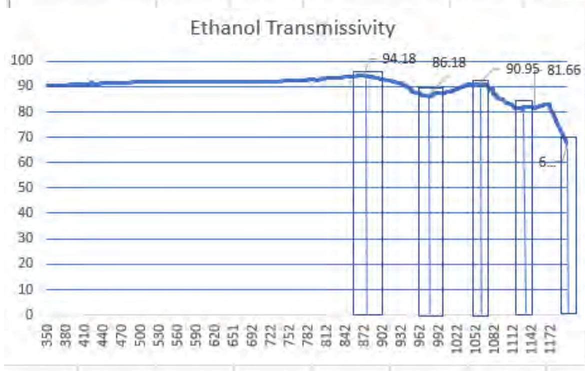
1) Either

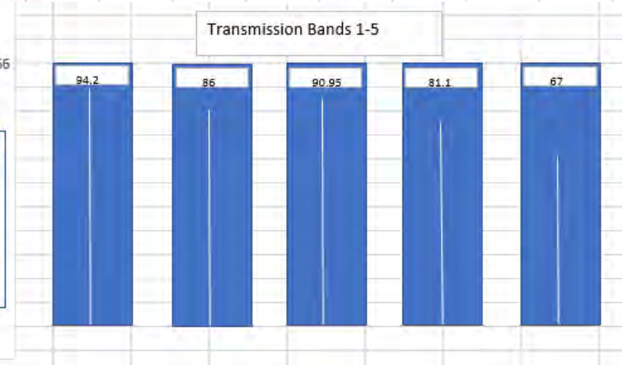




Then

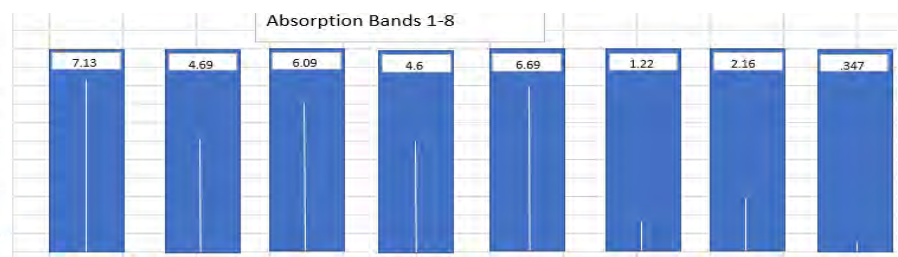
2) Ethanol



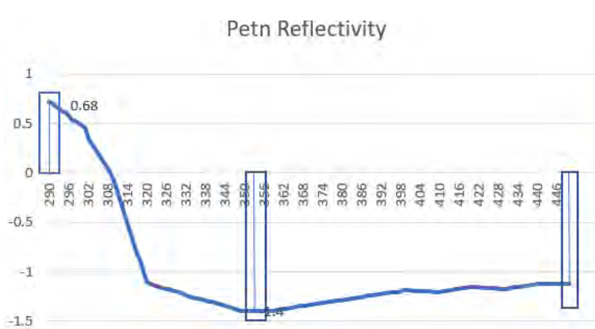


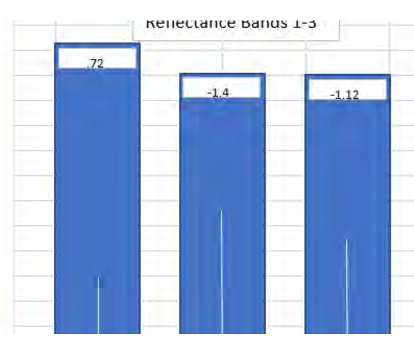
Then

3) NCO2



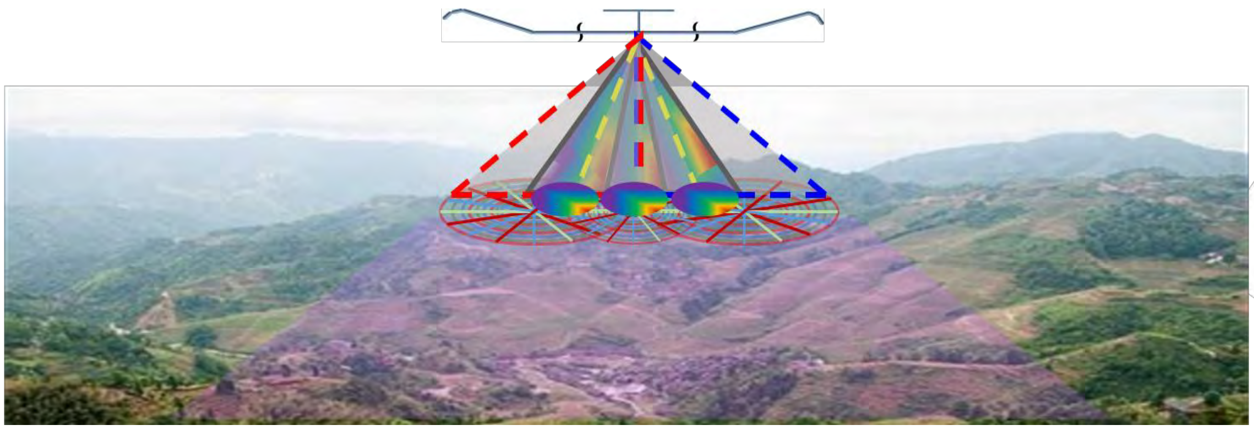
4)Petin

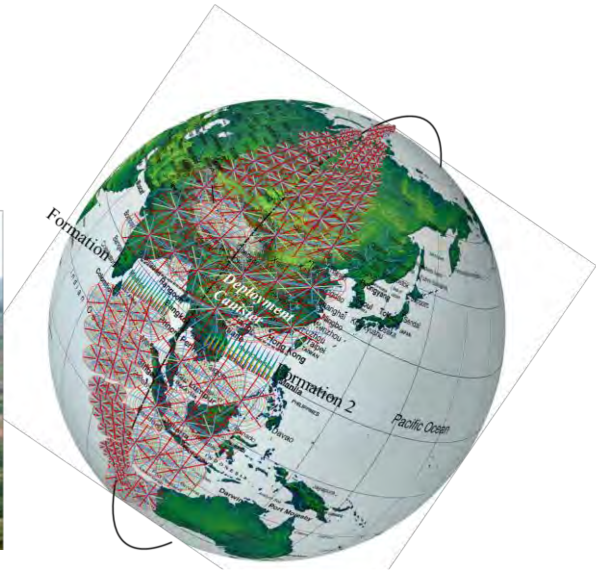




Approach with caution

Questions?





Additional Information;
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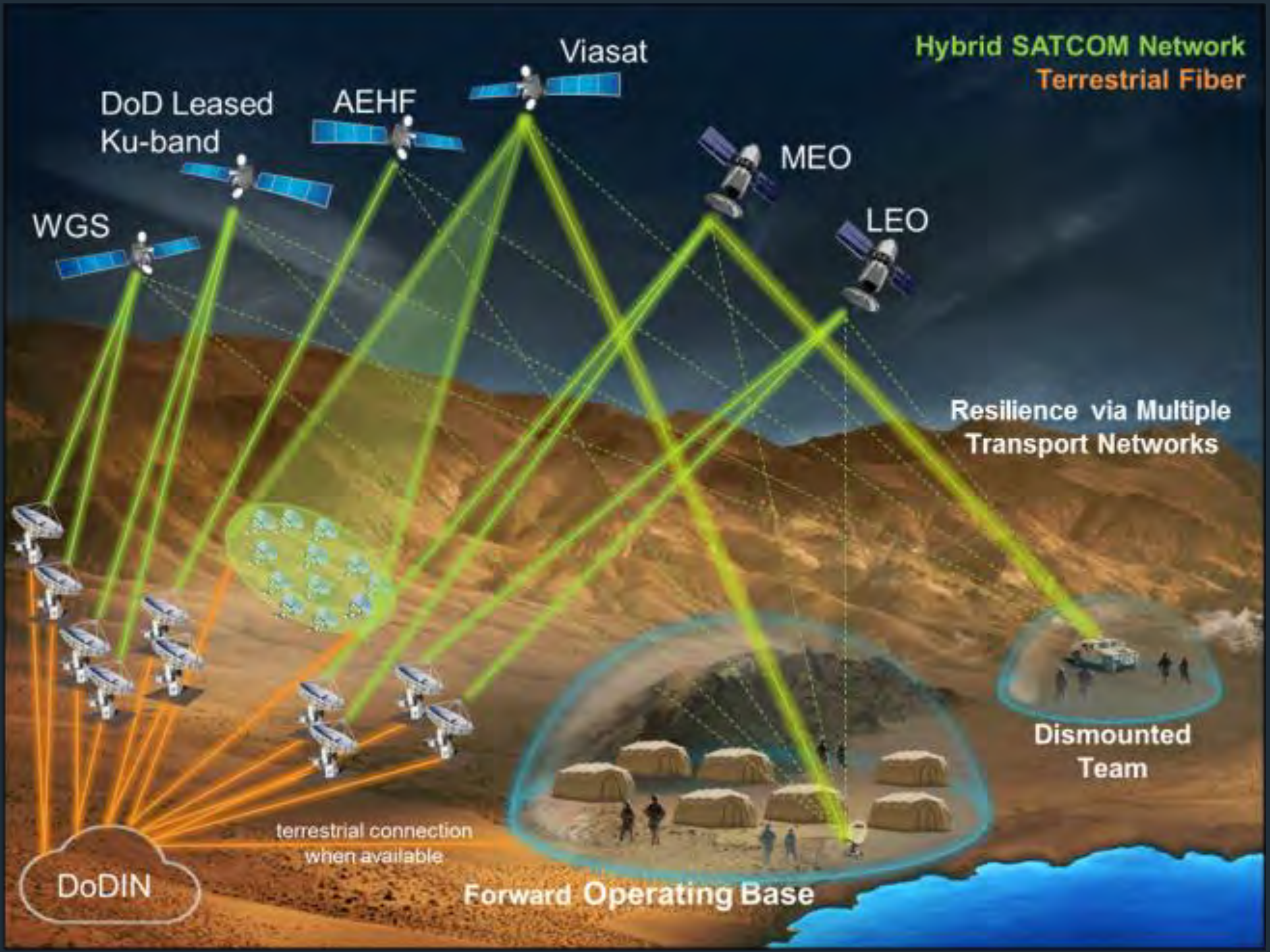
727 686 2702
Arnold.Kravitz@gmail.com

Resilient Communications with Hybrid Adaptive Networking

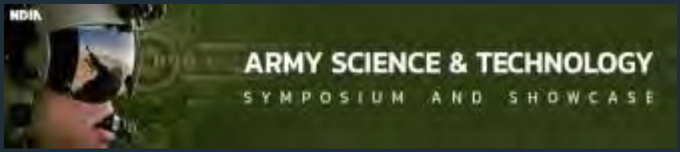


Mr. Craig Miller

Vice President & Chief Technology Officer

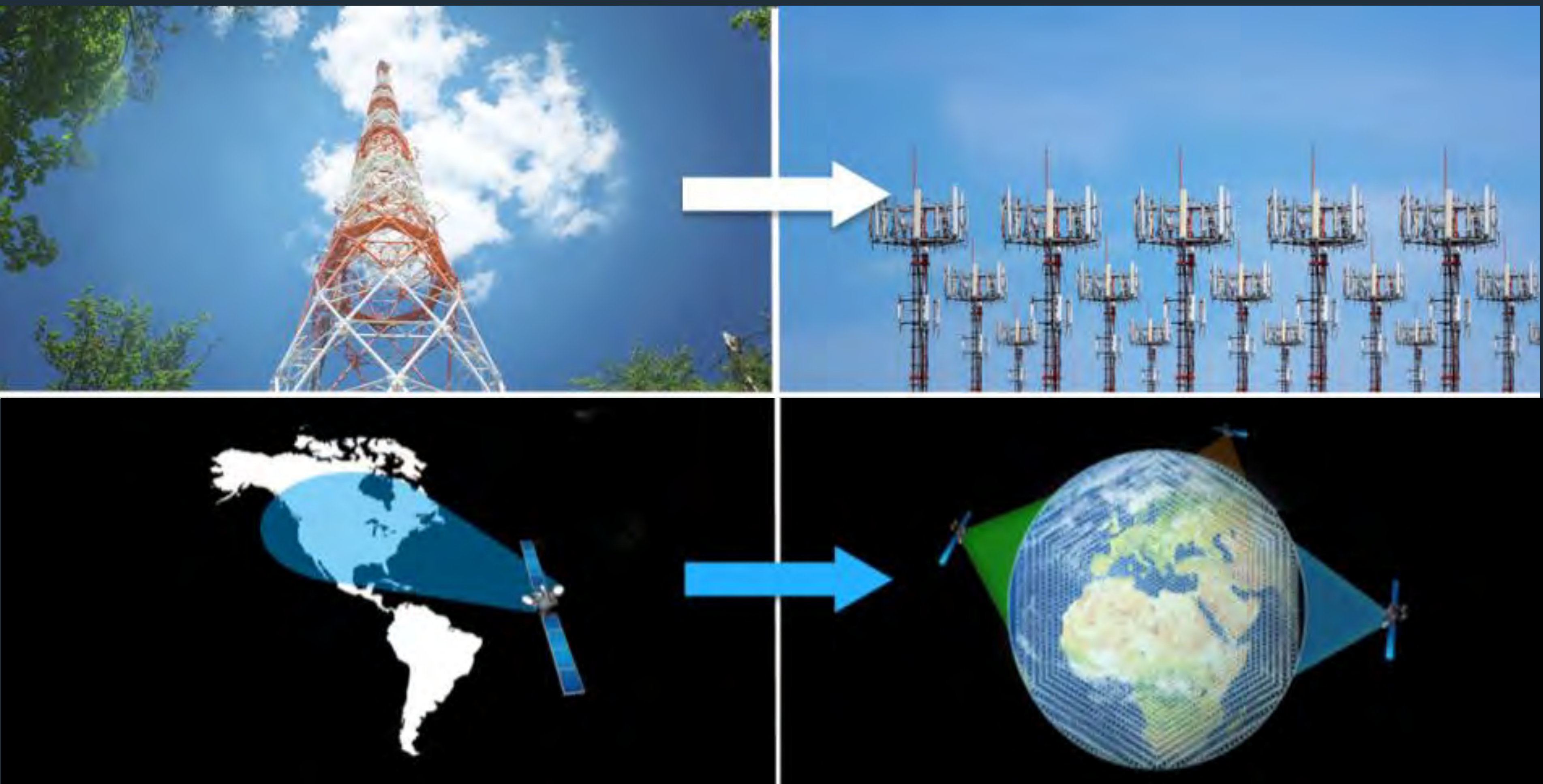
21 August 2018

Viasat



Transition from Broadcast to Interactive Broadband

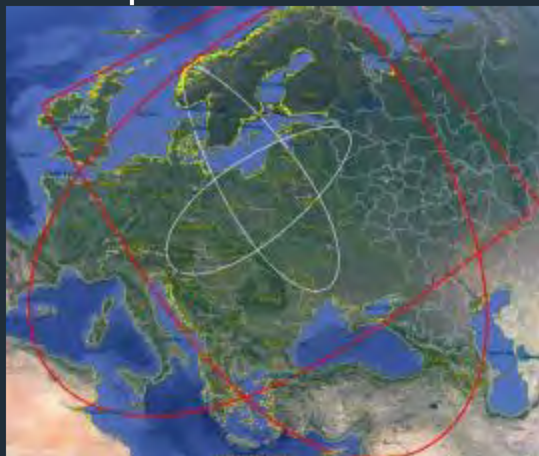
Revolutionized Wireless Communications … a 2nd Time



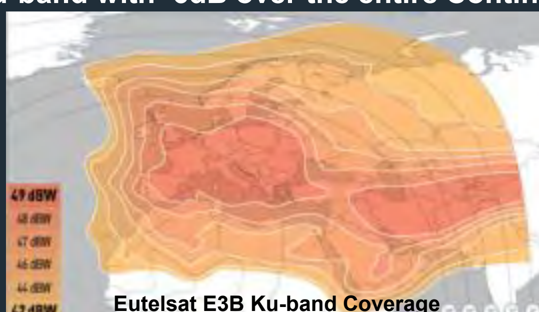
Broadcast to Interactive Broadband

Systems the Army employs

Ka-band Spot Beams -3 & -30dB contours



Ku-band with -6dB over the entire Continent

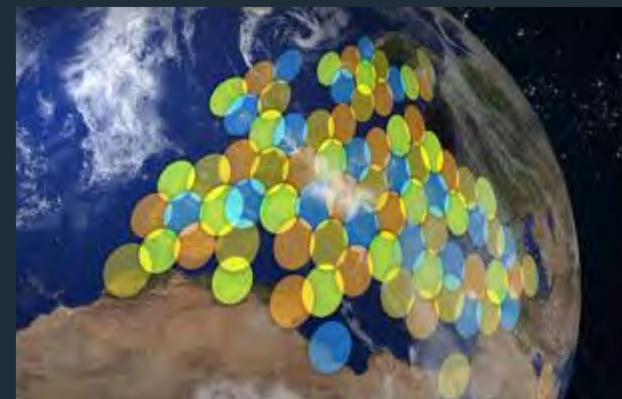


Eutelsat E3B Ku-band Coverage

Only One Transmitter using the same frequency at the same time
(Thus, they are susceptible to Interference)

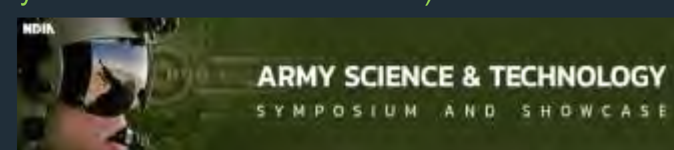
Commercial Data/Broadband Satcom

Eutelsat KaSat Beam Counters



Notional ViaSat-3 Beam Counters

1000s of Transmitters using the same frequency at the same time
(Thus, they are hardened for Interference)



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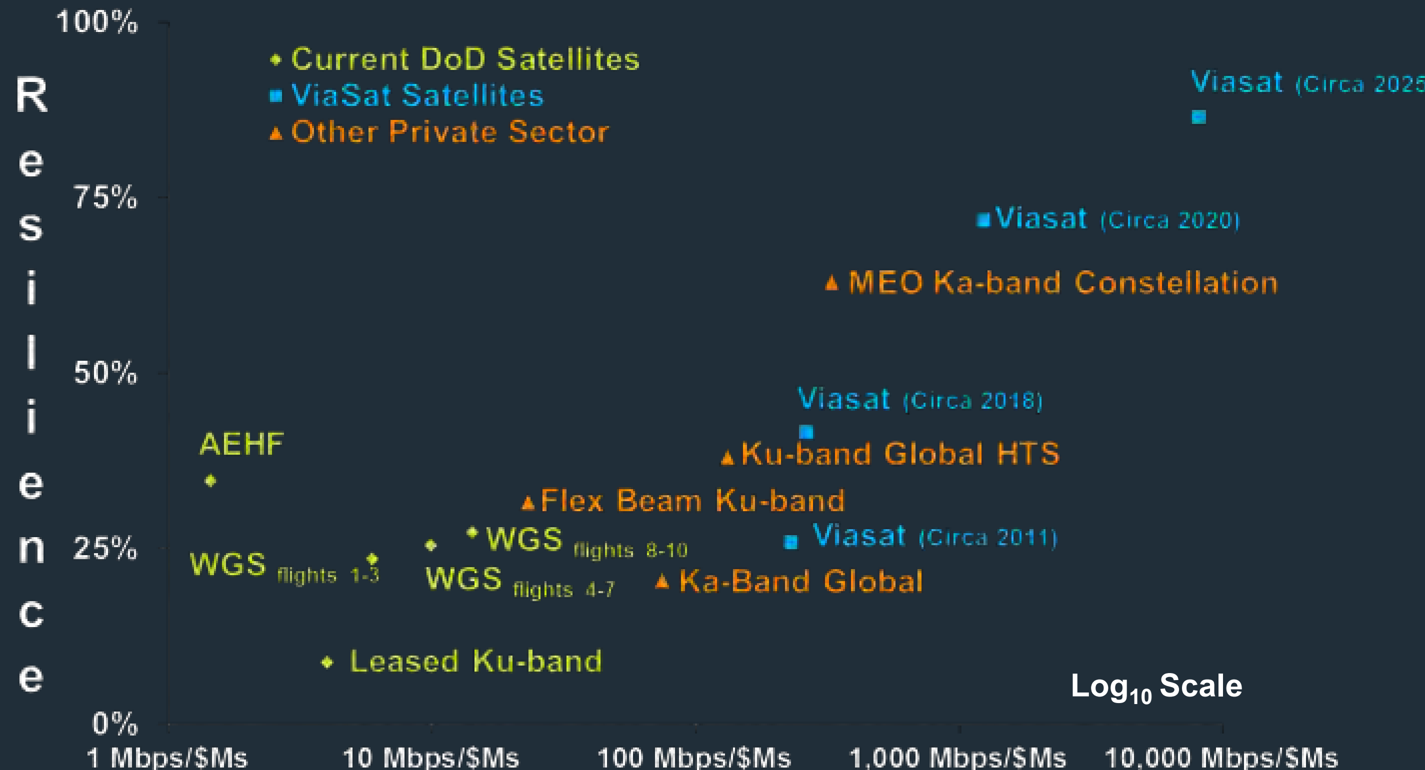
Viasat’s AoA – Resilience and Affordability Assessment

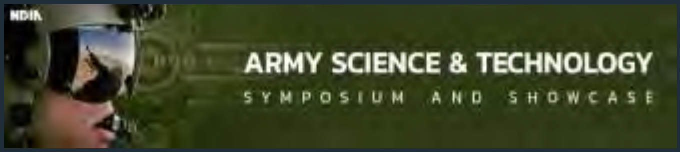
Current DoD & Private Sector Satcom Systems

Resilience Score:

- Beam Roll-off distance to -30dB
- Nulling/Processing Rejection
- Bandwidth Rejection
- GPS Independence
- Cyber Defense
- Immunity to Monitoring
- Kinetic (Multi-path)
- LPI/LPD modes
- Scintillation modes
- High Density Deployments
- Emitter Geolocation
- Protection against future threats



Capacity Cost (Mbps generated per $Ms investment in Space)



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Layering dramatically increases Resilience & Deterrence

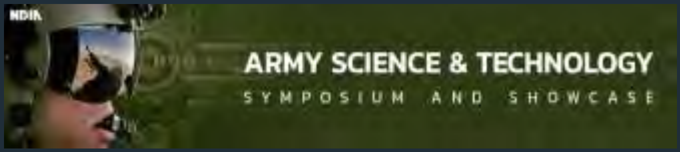
Resilience improvements in the European Theater

Hybrid Network (Circa 2018)	Network Resilience Score
European Ka-band HCS	26%
Ka-band Global HCS	20%
WGS (8-9)	27%
Overall Hybrid Network Resilience	56.97%

Hybrid Network (Circa 2022)	Network Resilience Score
AEHF	35%
Ka-band Global HCS	20%
WGS (8-9)	27%
ViaSat-3 Constellation	86%
MEO Ka-band Constellation	63%
Overall Hybrid Network Resilience	94.71%

Achieves immediate Resilience & Deterrence improvements with Legacy & without costly investments in New Systems

Viasat



Viasat's AoA Recommendation - Deter Aggression and Warfighting in Space/Cyber* by Leveraging DoD & Commercial Layers

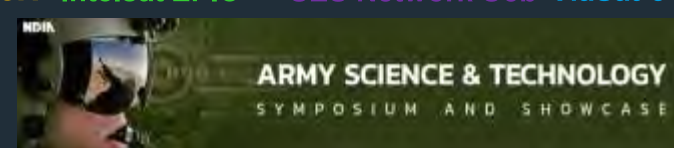
Enhance Deterrence with each new layer:

- Imposes significant new cost on Targeting & Developing effective attack vectors in all Satcom Network Domains
- Reduces likelihood of successful attack (including A/J, PNT denied environments, Cyber attacks, Kinetic-Space/Ground, Teleport Exploitation, Scintillation, etc.)
- Informs the market (and Adversary) of their use

Notional Army Exercise Circa 2022

WGS-2 & 3 KASAT Inmarsat GX Intelsat EPIC[NG] SES Network O3b ViaSat-3

Eliminate Adversary Effects & Serve Growing Wideband Demand



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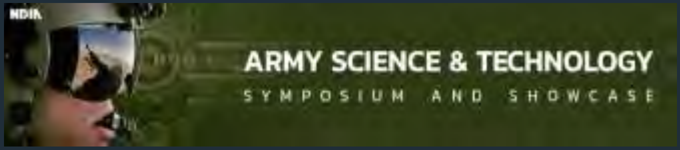
* US STRATCOM Commander Gen. Hyten: http://secure.afa.org/events/Conference/2017/recordings/Wednesday-340-COCOM.asp

3 Major shifts in Satcom Market create Opportunity to:
Improve Performance, Resilience, Deterrence, & Affordability

1. Adversaries are preparing to deny Satcom (purpose-built and commercial)
2. Commercial Satcom Service Providers now employ Data or Broadband Satellite Networks (Internet Broadband Constellations for Commercial Air, Maritime, Business Enterprise & Gov't/Military customers)
   - Order-of-Magnitude better Performance (throughput)
   - With Protected Satcom Capabilities – Limited Jamming effects to under 25nm & Scintillation effects to the localized area.
   - Order-of-Magnitude better Affordability
3. Multiple Global Satcom Data Services are Operational Today & more are in Deployment
   - Today: Inmarsat GX, Intelsat EPIC, SES Networks, EchoStar, Viasat
   - New Entrants: OneWeb, LeoSat, TeleSat, SpaceX, etc.

Army can now layer Satcom Services for:
Higher Performance, Enhanced Protected Satcom, & Increased Deterrence

Viasat



Air Force Civil Engineer Center

Energy Efficient "Shelter in Shelter" Concept for Large Expeditionary Structures

21 August 2018

Reza Salavani
AFCEC/CXAE
Tyndall AFB, FL

Energy Efficient "Shelter in Shelter”
Overview

- Joint Army/Air Force program
  - Energy saving, security, resiliency for expeditionary shelters
  - Particular emphasis on high energy/soft-wall shelters
  - Integration of technology options achieved goal of >50% increase in energy efficiency (Not linearly scalable to medium and large shelters)

- Most energy efficient option for large shelters is a "Shelter in Shelter" (SIS) concept
  - Confine environmental conditioning to a small area rather than conditioning the whole shelter

Energy Efficient "Shelter in Shelter" Concept

- Expeditionary shelters are primary power consumers and inherently inefficient for environmental heating and cooling
- Benefits of SIS:
  - Reconfigurable work areas within large structures
  - Localized environmental cooling or heating
- Will realize most cost benefits for large deployed military shelters;
  - Medium Shelters System (MSS), and Large Area Maintenance Shelters (LAMS)

MSS: 52’x30’x15’ = ~23,000 ft^3

LAMS:192‘x75‘x31‘ = ~450,000 ft^3

Energy Efficient "Shelter in Shelter" Methodology

Prototype SIS:

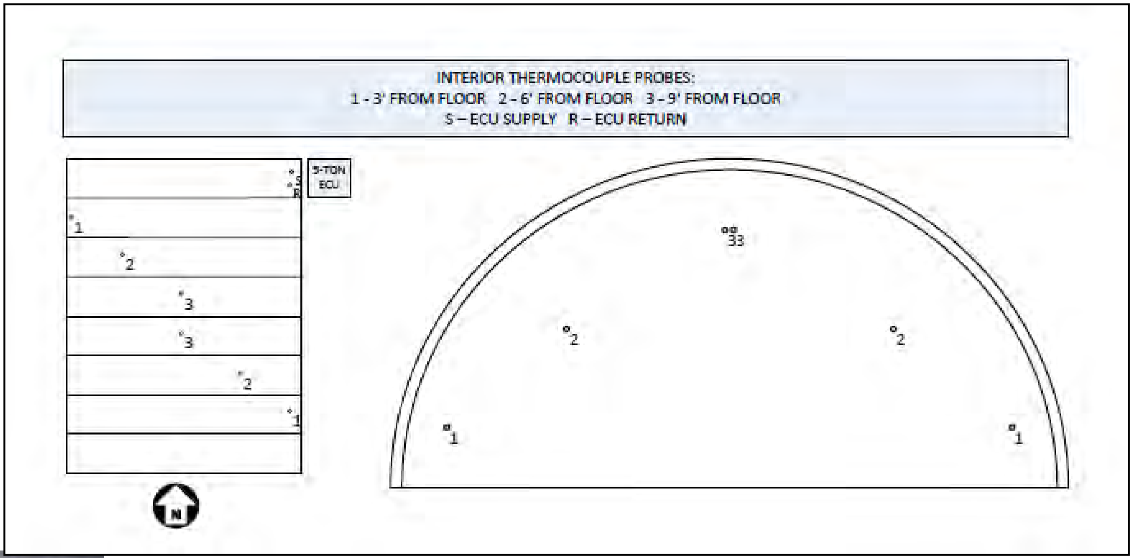
- **Small gable-style shelter (14’x14’x7’) inside a Medium Shelter (MSS)**
- **Baseline: MSS running on a conventional ECU**
- **All testing completed at “Tent City” AFCEC test site at Tyndall AFB, FL**

SIS Inside View

AFCEC Tent City Test Site
Tyndall AFB, FL

Energy Efficient "Shelter in Shelter" Methodology (Continued)

Temperature Sensors Location in Baseline MSS



Metrics:
- Interior temperatures
- Power consumption

SIS prototype has stand-alone portable A/C, insulated liner and LED lights

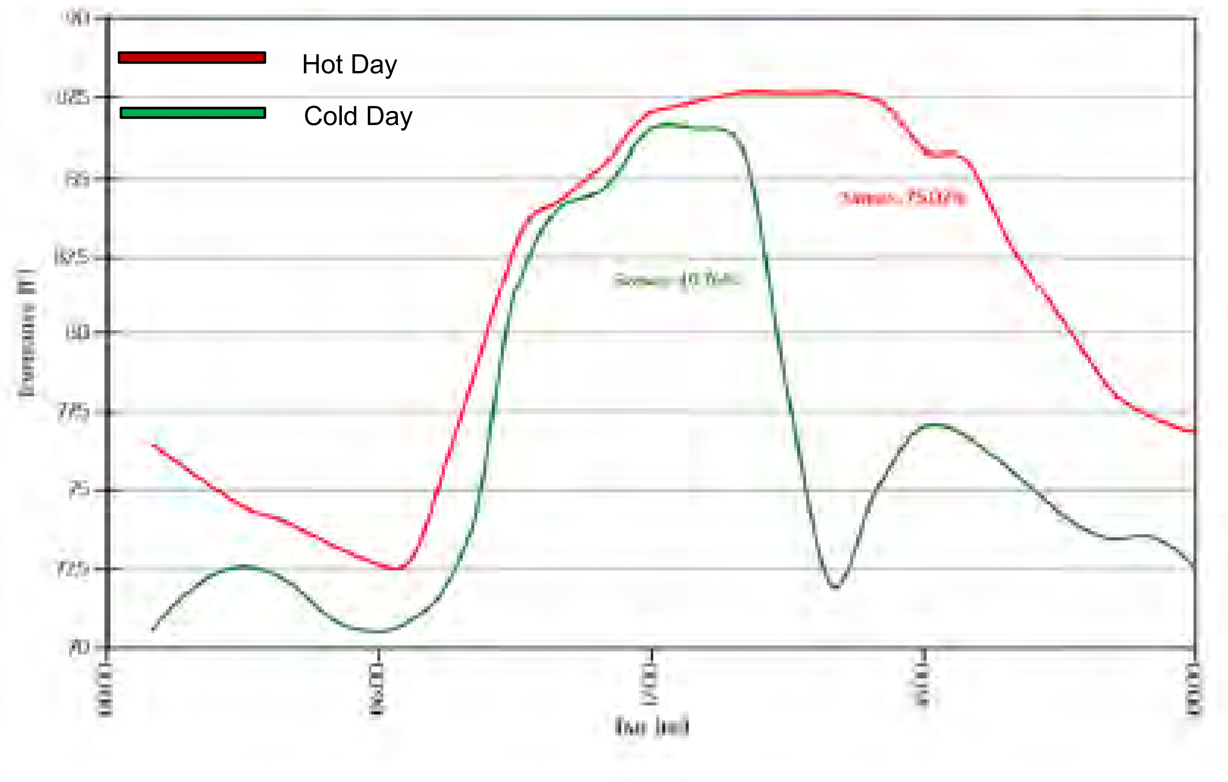
Energy Efficient "Shelter in Shelter" Results

	Baseline	SIS
24 hour	91.5*	21.8
Early Morning (0000-0800)	12.3	4.8
Daytime (0600-1800)	71.9	13.1
Peak Hours (1100-1900)	52.6	9.6
Evening (1600-2400)	22.0	7.5

Energy demand (in KWH) Comparison throughout different time periods

*These results has an error range +/- 5%

Energy Efficient "Shelter in Shelter" Results (Continued)



Impact of Environmental Conditions on Energy savings for SIS

Energy Efficient "Shelter in Shelter" Summary

- Energy savings of 49-75% were achieved by the SIS system compared to the baseline shelter,
  - Efficiency dependent upon ambient environmental conditions
  - High outdoor temperatures and high humidity require more power consumption from ECU
  - AC in the SIS remains constant; shaded by the exterior shelter
- Cumulative energy savings (1 month test) were ~65% over 24 hour period
  - Average daytime savings of 74% (ambient conditions of 85°F) = ΔT of 15°F
- Energy consumption, per sq. ft., is as follows:

  0.018 kwh/ft^2............For SIS Shelter

  0.065 kwh/ft^2............For Baseline Shelter

Energy Efficient "Shelter in Shelter" CONCLUSION

- The SIS concept provides a workspace that is modular and configurable
- Designated heated/cooled environmental area
- Potential energy efficiency >50% is achievable
- Energy efficient solution for large expeditionary shelters
- Can incorporate additional functionality, i.e. blast resistance, fire resistance, controlled environments (clean room, mortuary, paint booth etc.)

Energy Efficient "Shelter in Shelter" Military Applications

Small structures inside LAMS

Source:https://www.bing.com/images/search?q=Lam%27s+Large+Area+Maintenance+Shelter&FORM=IDINTS

Energy Efficient "Shelter in Shelter" Real World Applications

Small shelter around Airbus Engine installation

Source:
https://airbus-h.assetsadobe2.com/is/image/content/dam/corporatetopics/innovation/Shelter_installation_03.JPG?wid=1196&fit=fit,1

Energy Efficient "Shelter in Shelter”

Questions?

Designing Scalable, Objective Assessments of Interpersonal Leadership Skills

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Army Science & Technology Symposium & Showcase
22 AUG 2018

The research described herein was sponsored by the Army Research Institute for the Behavioral and Social Sciences, Department of the Army (Contract No. W5J9CQ11D0001-0026). The views expressed in this paper are those of the author and do not reflect the official policy or position of the Department of the Army, DOD, or the U.S. Government.

Interpersonal Leadership Skills

- Army Leaders do more than tactical decision making

- Successful Leaders
  - Motivate
  - Inspire / Influence Others
  - Build Trust
  - Develop their Soldiers
  - Create a Positive Environment
  - Communicate Effectively

- How systematically are these skills assessed, trained, and refined currently?

Assessment Options

- Self-report
  - Easy to administer
  - Inexpensive
  - Suffer from respondent biases
  - Susceptible to “faking” and “ability to identify criteria”
- Live
  - Expert evaluators
  - High fidelity
  - Resource intensive

A Novel Approach to Assessment

- Scenario-Based, Free-Response Assessments
  - Computerized scenarios designed to elicit leadership behaviors
  - Inputs are made in real-time as free-text responses to unfolding conversations
  - Virtual agents react to inputs via natural language processing algorithms that assess how inputs should progress the narrative
- Live assessments made by Officer Candidate School instructors served as criterion data in validation study

Sample Scenario

- “Hand Receipt”
  - Vignettes
    - Gossiping subordinate
    - Peer pressure to sign inventory form prematurely
    - Platoon Sergeant offers to take responsibility for finding missing items
    - A Staff Sergeant berates a Private and provokes a fight
  - Targeted Interpersonal Leadership Skills
    - Creates a Positive Environment
    - Leads Others / Leads by Example
    - Builds Trust

Initial Results

- Match rate for natural language processing algorithms reached an average of nearly 80% across all vignettes
  - Vignettes with 200 or more responses averaged 81.5%
  - Vignettes with fewer than 100 responses averaged 67.8%

- Differences in behaviors across participants
  - Within the scenarios, candidates rated highest on interpersonal leadership skills by instructors more consistently
    - Corrected unprofessional behavior
    - Offered constructive suggestions to solve problems
    - Avoided placing blame prematurely

Next Steps

- Future development for the scenario-based, free-response assessments will focus on
  - Allowing nonlinear conversations to unfold
  - Making agents more flexible by tracking emotional states, etc. across vignettes
- Identify vignettes characteristics most responsible for improved language matching and better predictive validity to improve assessment techniques overall

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Strategic thinking mindset:

Concept development and assessment of strategic thinking aptitude

Dr. Will Weyhrauch

U.S. Army Research Institute for the Behavioral & Social Sciences

Army Science & Technology Symposium & Showcase

Aug 22, 2018

Washington DC

Strategic Thinking

- What is it?
  - Cognitive process
  - Synthesis and creative insight
  - Improve organizational competitive position
- Why is it important for the Army?
  - Identify future threats to national security and exploit opportunities to improve security
  - Leaders able to visualize potential futures, anticipate change, mitigate risks, and shape the security environment.
  - Strategic Thinking = Anticipated Events = Time = Options
- Why do we need to assess it?
  - Identification
  - Selection
  - Development
  - Evaluation

Mindset as a foundation for competencies

Systems and synthesis

Creativity

Directionality

Criticality

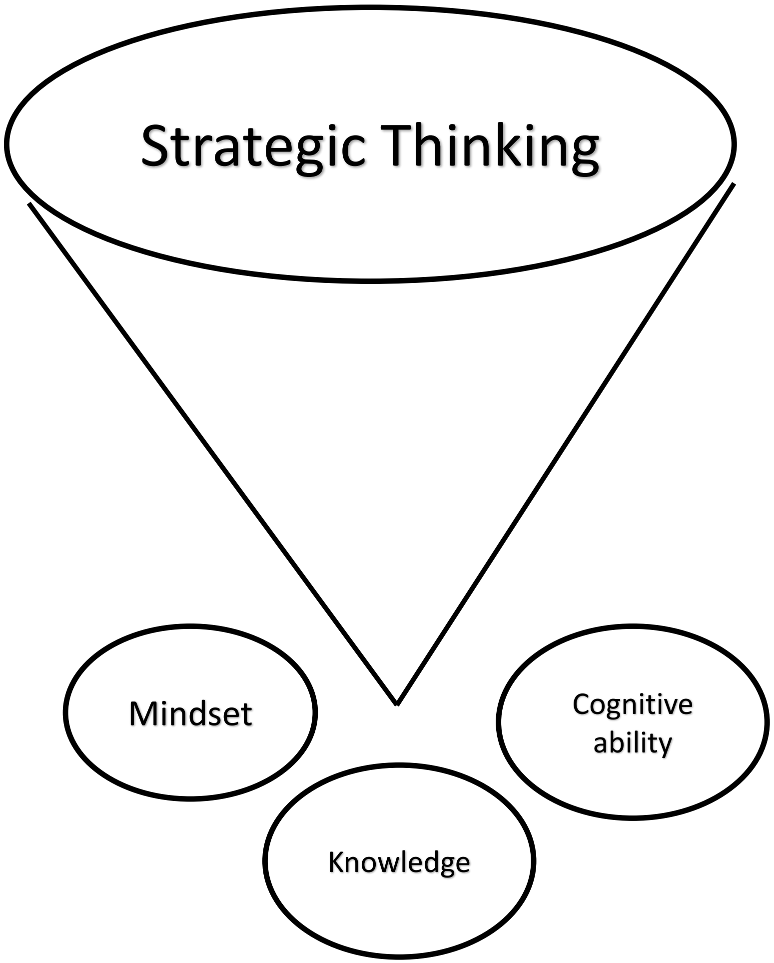
Awareness of time

Adaptability and opportunism

Breadth and inclusion

Self-awareness and self-control

Action learning



Characterizing a mindset for strategic thinking

- Flexibility
  - Willingness to adjust when conditions change or new information is presented
- Humility
  - Comfort with acknowledging a wrong or incomplete understanding; the tendency to question one's understanding
- Inclusiveness
  - Welcoming of information and perspective from a broad range of sources

Sample SJT Item

CPT Clark was attached as civil-military support to a humanitarian dental effort. CPT Clark was there to facilitate interaction with the local population and spread the word about the services available. However, the local government insisted that information about the services could only be distributed with approval and through the national government. However, the representatives CPT Clark had to work with were antagonistic and slow in responding and generally publicizing the effort.

If you were in CPT Clark's position, and given the following options, what would you personally most likely *and* least likely do?

A. Arrange a meeting with the local government officials and try to understand more about why they are resistant.
B. Request that someone above you in the U.S. chain of command reach out to someone higher in the local government to bypass the resistance.
C. Try to informally publicize your services through word of mouth, but nothing official.
D. Comply with their bureaucratic processes for publicizing the efforts, accepting the delays in order to maintain a good relationship with the government.

Most Likely ☐ Least Likely ☐

Sample Self-Report Items

Instructions: Please consider your general tendencies when confronted with an unusual problem or unclear situation. Rate each of the following statements on the scale below based on how strongly you agree that the statement reflects your general tendencies. Circle one.

5 = Strongly agree
4 = Moderately agree
3 = Neither agree nor disagree
2 = Moderately disagree
1 = Strongly disagree

When I am confronted with unusual problems or uncertain situations…	*Strongly disagree*	*Moderately disagree*	*Neither agree nor disagree*	*Moderately agree*	*Strongly agree*
1. My judgment is usually not changed by others' opinions....................	**1**	**2**	**3**	**4**	**5**
2. I trust in what has been successful in the past.	**1**	**2**	**3**	**4**	**5**

Observed Psychometrics

Reliability

SJT

- Flexibility α = .31
- Humility α = .18
- Inclusiveness α = .34

Self-report

- Flexibility α = .64
- Humility α = .35
- Inclusiveness α = .49

Construct Validity

SJT

- Flexibility r = .31
- Humility r = .36
- Inclusiveness r = .21

Self-report

- Flexibility r = .27
- Humility r = .15
- Inclusiveness r = .31

Potential Utility for the Army

- Individual leader self-awareness
- Guide for self-development, personal growth
- Talent management
- Metric of change for broadening assignments or PME
- Part of a commander's leader professional development program with staff

Future work: refinement for improved psychometrics and adaptation to other Army populations

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Development of a game-based assessment of systems thinking ability: Initial model and construct validation

Dr. Alexander P. Wind

Human Aptitude Assessment Panel

Dr. Kara Orvis, Chair

Army Science & Technology Symposium and Showcase

21 August 2018

Cory Adis, Michelle Wisecarver, Chelsey Hartzler, Personnel Decisions Research Institutes
Kristophor Canali, U.S. Army Research Institute

Purpose

The purpose of this research is to develop a game-based assessment of a complex cognitive construct- Systems Thinking Ability- for the U.S. Army.

Phase 1-Develop / Validate Tests of STA Antecedents	Phase 2- Develop and Validate STA Assessment Game	Follow-up- Support implementation and adoption by Army
Completed SEP2016	Target MAR2021	+24 Months

Army Sponsors

Cyber Center of Excellence
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Higher-order Cognitive Assessment

Cognitive tests, such as ASVAB, are useful but have limitations:

They measure a few core capabilities (e.g., mathematical reasoning, vocabulary)

Composite scores (e.g., Science & Technology) are aggregates of section scores and may not fully reflect test takers' capability in namesake domain

Direct Measure of higher-order cognitive capabilities has advantages

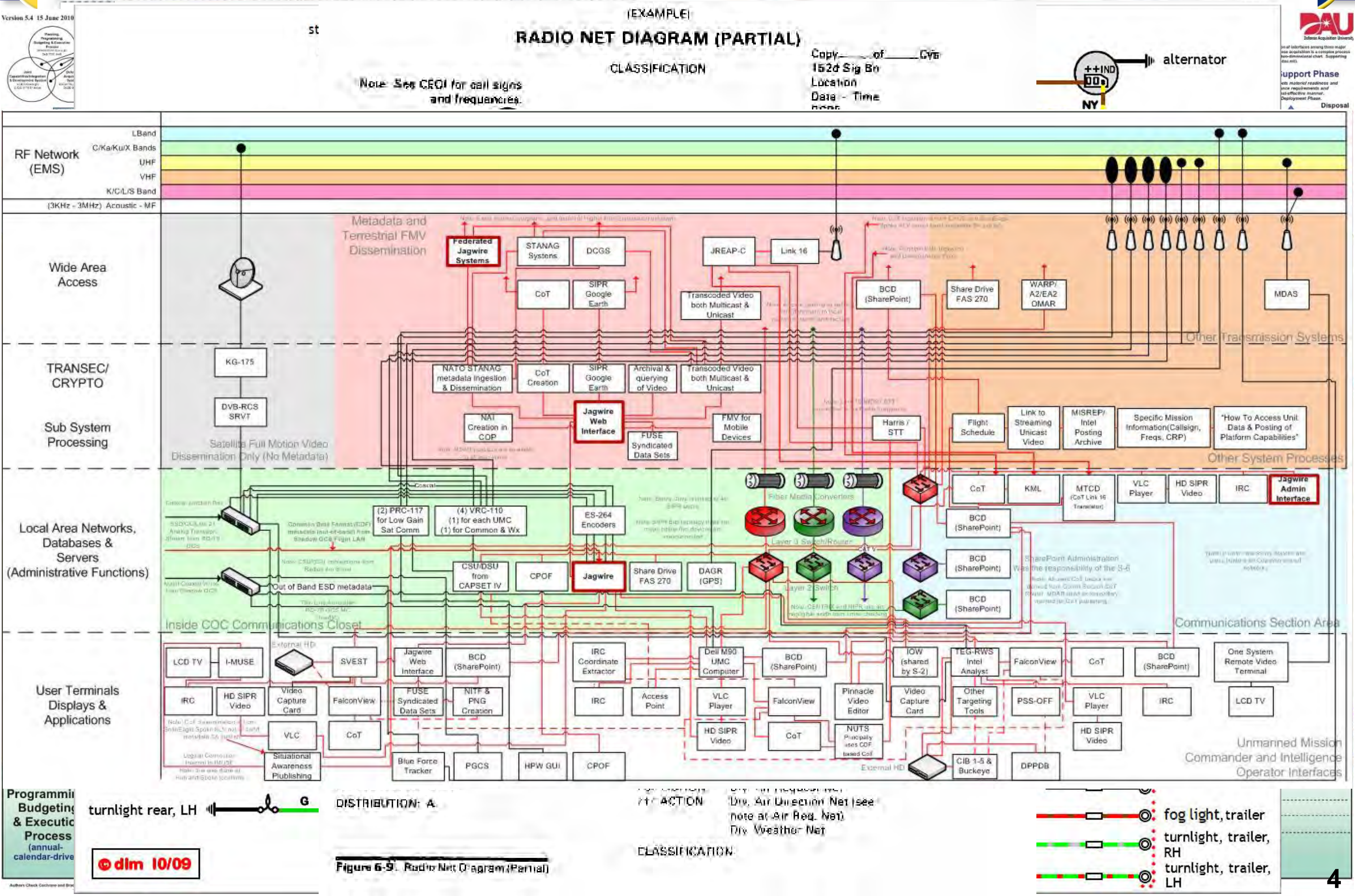
For some MOS, measurement of higher-level capabilities (e.g., Systems Thinking Ability) could better identify the best-suited for the field

Could allow differentiation of those with high general intelligence to ensure such Soldiers are best utilized (enhances Talent Management)

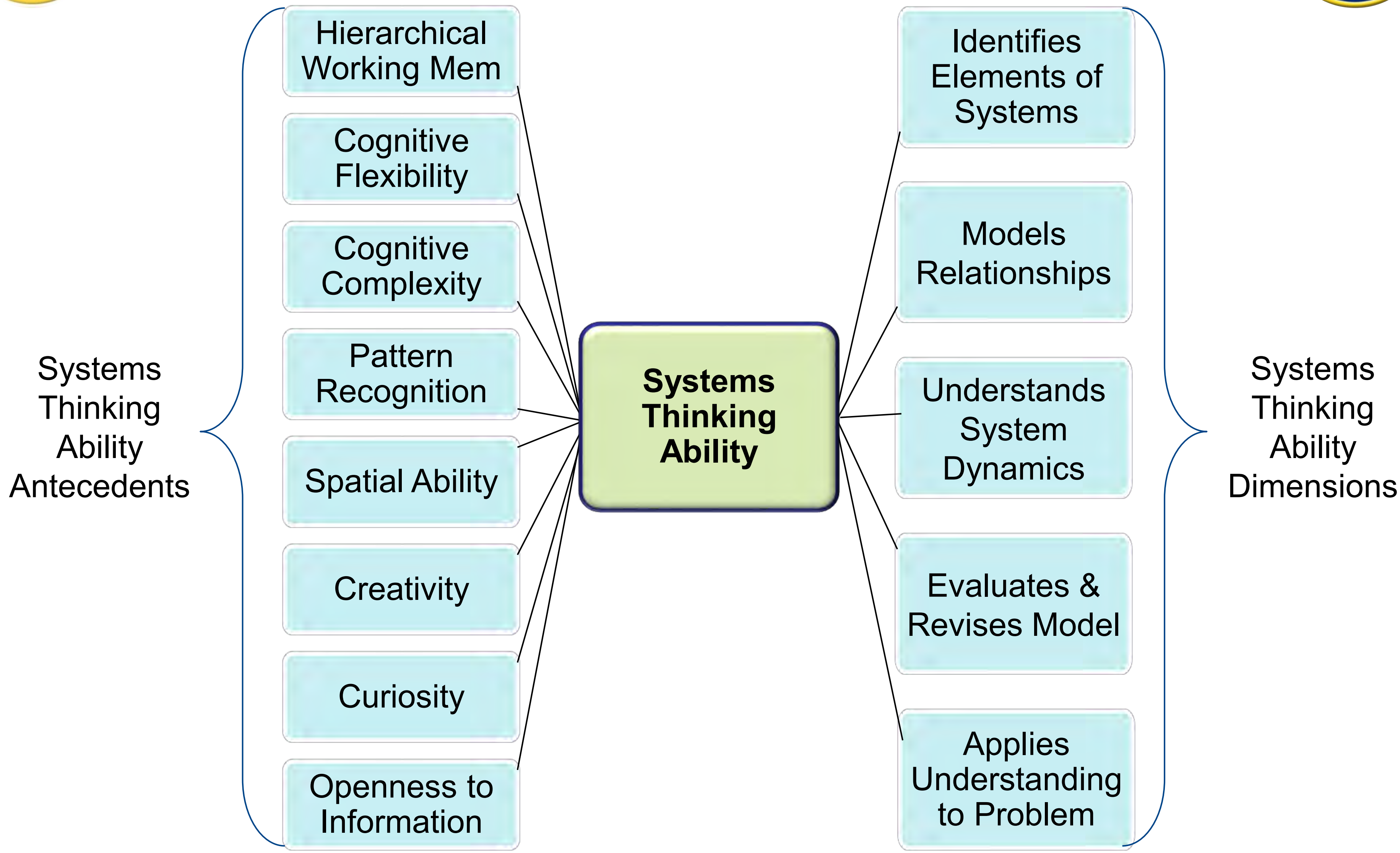
New technology is opening up new avenues to assessment of such capabilities, but much research is needed.

One higher-order capability with promise for utility is **Systems Thinking Ability (STA)**

Systems Thinking Applications in the Army



Defining & Measuring STA



For a complex multi-faceted construct, traditional assessment media may be insufficient.

Game-based Assessment

ARI is exploring game-based assessment for measuring Systems Thinking Antecedences and Processes

Advantages of Game-based Assessment

- Intrinsically motivating / engaging
- Can observe and measure behavior and processes rather than just item response
- Secure (no items to expose)
- Discreet and covert measurement (test taker doesn't know what counts or how)
- Adaptable to individual test takers
- Customizable to different needs (e.g., selection for different MOS)

Research Questions / Challenges

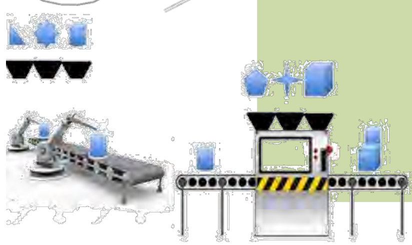
- What are the boundaries to what can be measured (e.g., response time, action efficiency, evidence of learning the game)?
- Can we design a system that can handle and use large amounts of data?
- How do we integrate large data pool into actionable assessment?
- What are the barriers to implementation (e.g., technology, measurement algorithms)?

Game Premise

About a month ago, a massive alien warship arrived at Earth, and sat menacingly on the horizon. Little is known about their intentions or capabilities. In the past few days, tensions between the aliens and the humans have been mounting. There have been isolated skirmishes and recent diplomatic and reconnaissance envoys have disappeared completely.

On a mission to investigate the alien ship more closely, your helicopter was captured and your entire unit was abducted by the aliens. The other members of your unit were quickly overtaken by alien mind control attacks, but somehow, you remain unaffected. You must fool your alien captors into believing you're under their control while you explore the ship searching for intel that the humans can use to overcome the invading aliens.

Measuring ST Antecedents



Each day on the ship, the player must join formation with the rest of the humans to undergo testing.

- Five ST "Antecedents" are captured during these daily activities, framed as alien experimentation or the aliens testing if their mind control is working.

Hierarchical Working Mem

Cognitive Flexibility

Cognitive Complexity

Pattern Recognition

Spatial Ability

Curiosity

Creativity

Openness to Information

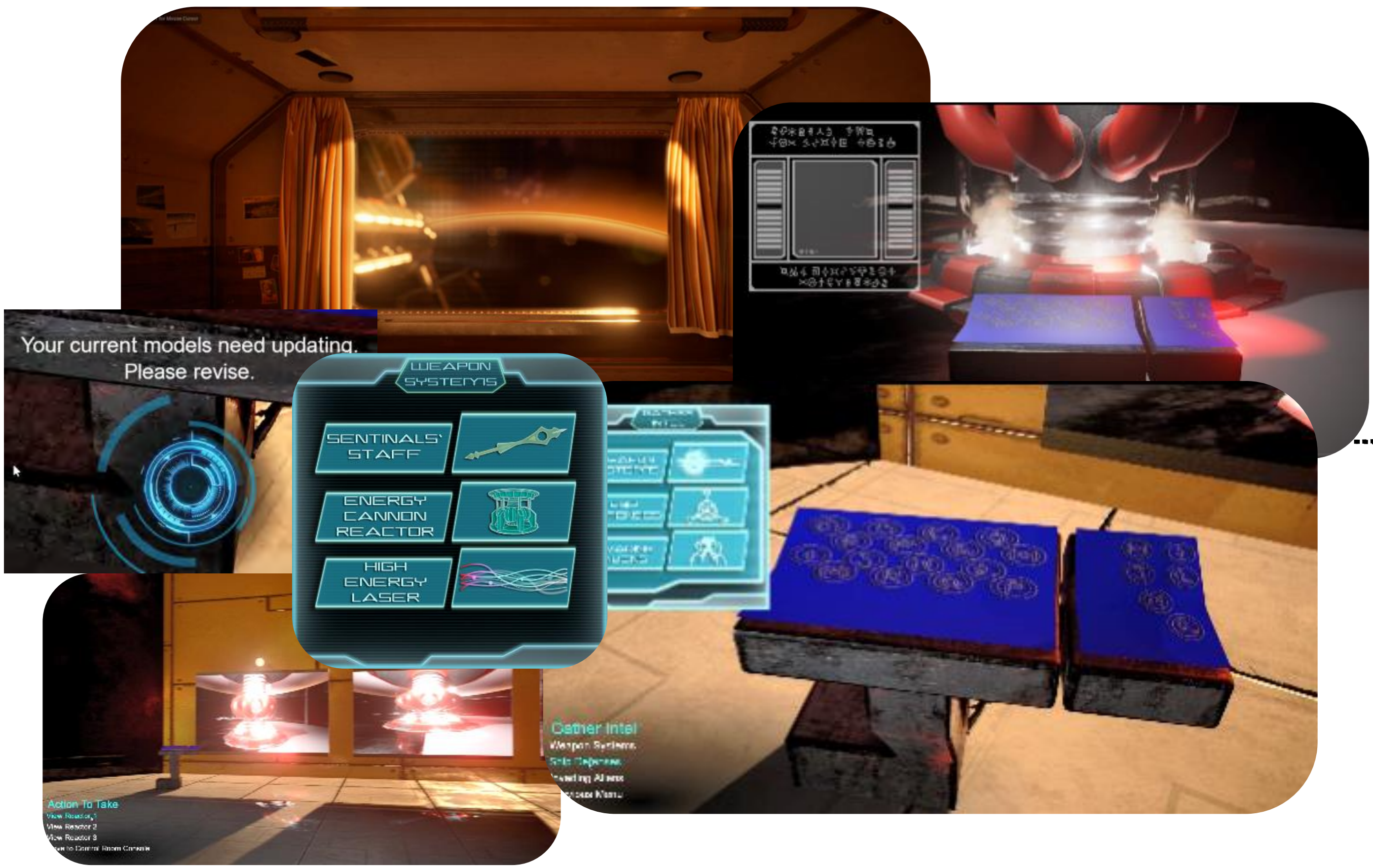
User moves around the ship exploring alien objects and machinery, collecting intel, and avoiding detection.

Three ST "Antecedents" are assessed through behavioral indicators collected as the user explores the ship, addressing the objectives and missions

Systems Thinking Ability Dimensions

When returning to the safe-room, the user can reflect on the systems s/he has seen.

Five Systems Thinking Ability Dimensions are captured from guided journaling, prompted activity, and via interaction with digital characters.



- Identifies Elements of Systems
- Models Relationships
- Understands System Dynamics
- Evaluates & Revises Model
- Applies Understanding to Problem

Summary

New technology is opening up new avenues to assessment of higher-order cognitive capabilities, but extensive research is needed

- Game-based assessment is one technology with promise to measure complex constructs

ARI is working on a game-based Systems Thinking Assessment

- Phase 1 developed and validated measures of 5 STA-related abilities
- Phase 2 will incorporate measures and will use in-game behaviors to look at traditionally hard-to-assess facets

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

Uncertainty-Aware AI&ML for Effective Decision Making

Dr. Lance Kaplan

Team Leader

US Army Research Laboratory

21 AUG 2018

APPROVED FOR PUBLIC RELEASE

U.S. ARMY RDECOM ARL RESEARCH LABORATORY

RESEARCH CONTEXT

Multi Domain Battle → Prevailing in a Complex World

Large-scale, cluttered, contested urban environment

Highly-dispersed team of human & robot agents accessing highly heterogeneous information sources

Dynamic in-flight learning & re-planning at the Speed of the Fight

Learning in new environments with deception from persistent threats

Research outcomes address CSA Priorities:
(i) Next Gen Combat Vehicles (primary) and (ii) Networks/C3I (secondary)

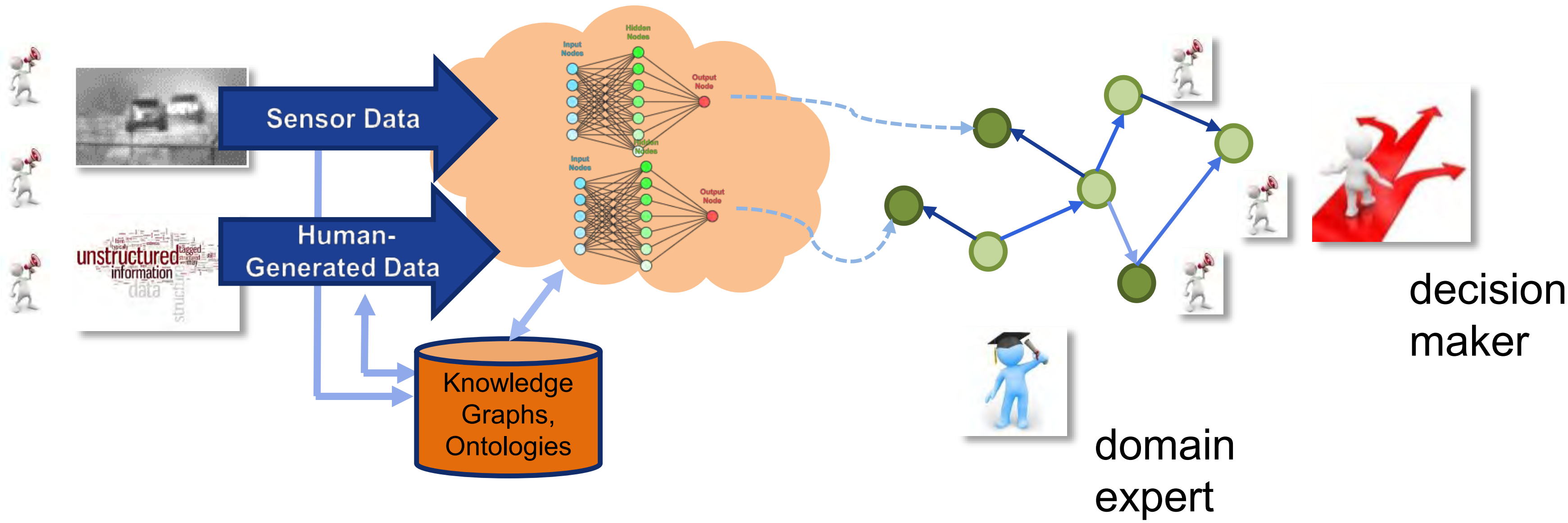
AI & ML RESEARCH CHALLENGES

AI & ML Research Gaps

Learning in Complex Data Environments	→ AI & ML with small samples, dirty data, high clutter → AI & ML with highly heterogeneous data → Adversarial AI & ML in contested, deceptive environment
Resource-constrained AI Processing at the Point-of-Need	→ Distributed AI & ML with limited communications → AI & ML computing with extremely low size, weight, and power, time available (SWaPT)
Generalizable & Predictable AI	→ Explainability & programmability for AI & ML → AI & ML with integrated quantitative models

Goal: To research and develop artificially intelligent agents (heterogeneous & distributed) that rapidly learn, adapt, reason & act in contested, austere & congested environments

AI&ML SYSTEM

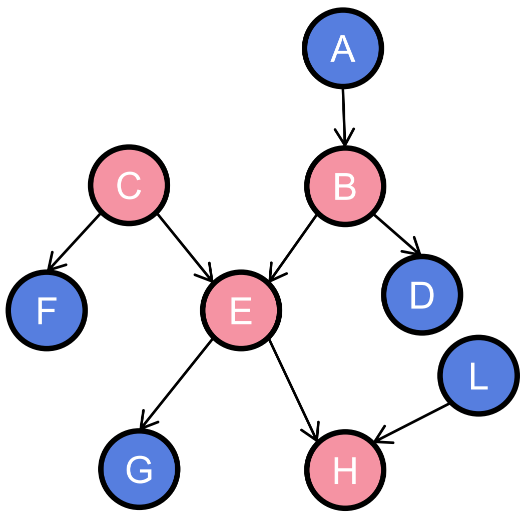


- **Limited training data**
- **Training and observational data can come from unreliable sources**

- **Reasoning with limited training data**
- **Characterization of uncertainty**
- **Explanations of uncertainty for the user**

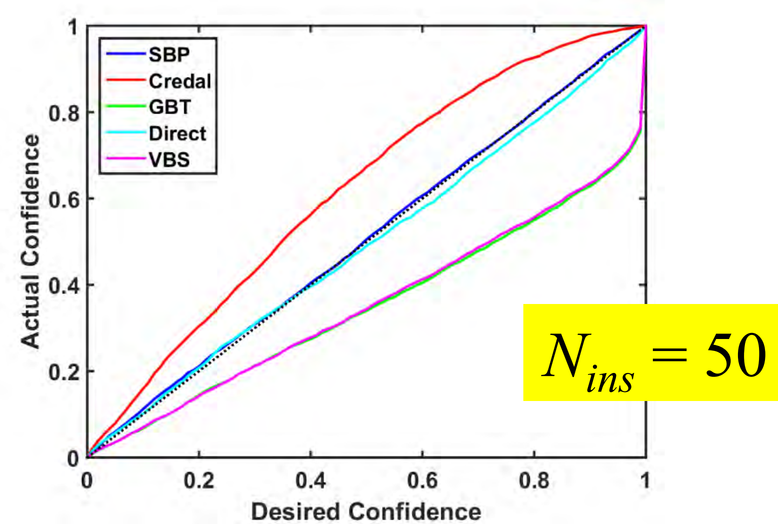
U.S. ARMY RDECOM ARL RESEARCH LABORATORY

SUBJECTIVE BAYESIAN NETWORKS



- Uncertain Bayesian networks due to sparse training data
- Efficient inference methods that generalize belief propagations

Uncertainty Characterization
(Desired Confidence Bound Divergence)

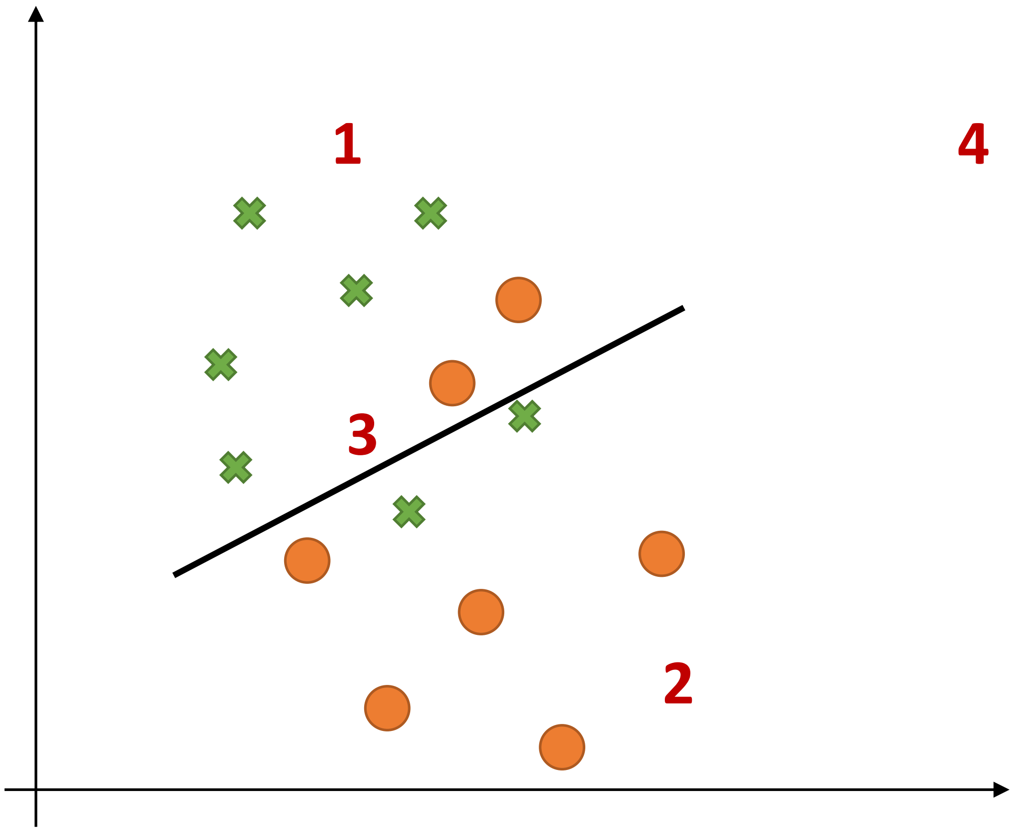


Accuracy
(Root Mean Squared Error)

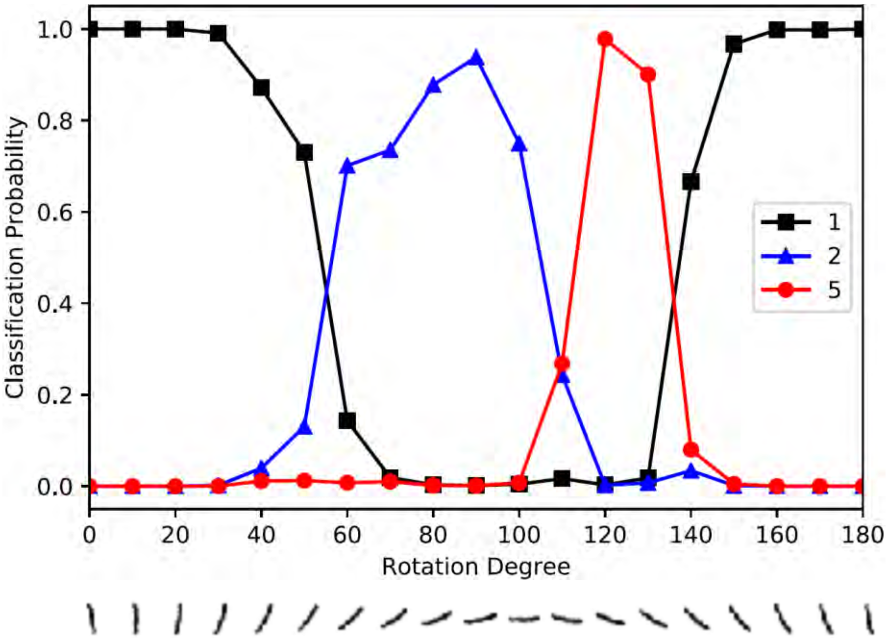
	SBP	Credal	GBT	Direct	VBS
Act.	0.112	0.121	0.124	0.256	0.123
Pred.	0.110	0.155	0.098	0.247	0.098

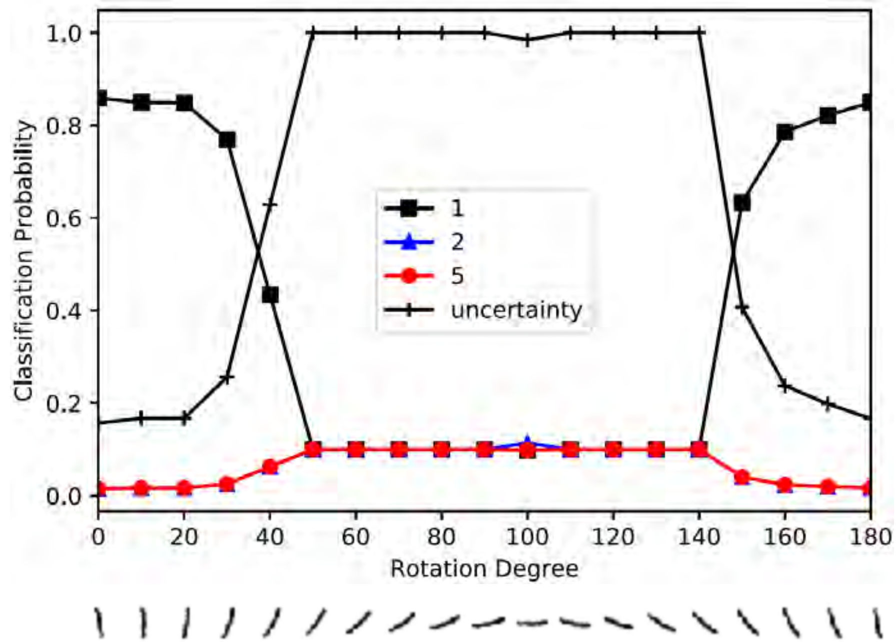
Ivanovska, Kaplan, Int. Jour of Approx. Reasoning, 2018

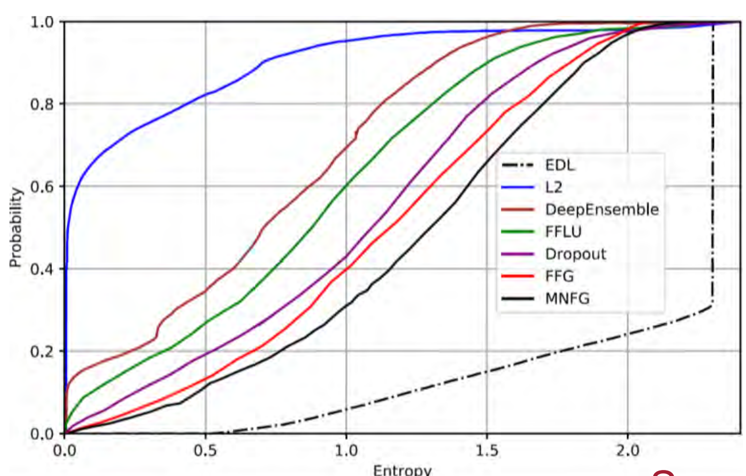
UNCERTAIN-AWARE MACHINE LEARNING



EVIDENTIAL NEURAL NETWORKS



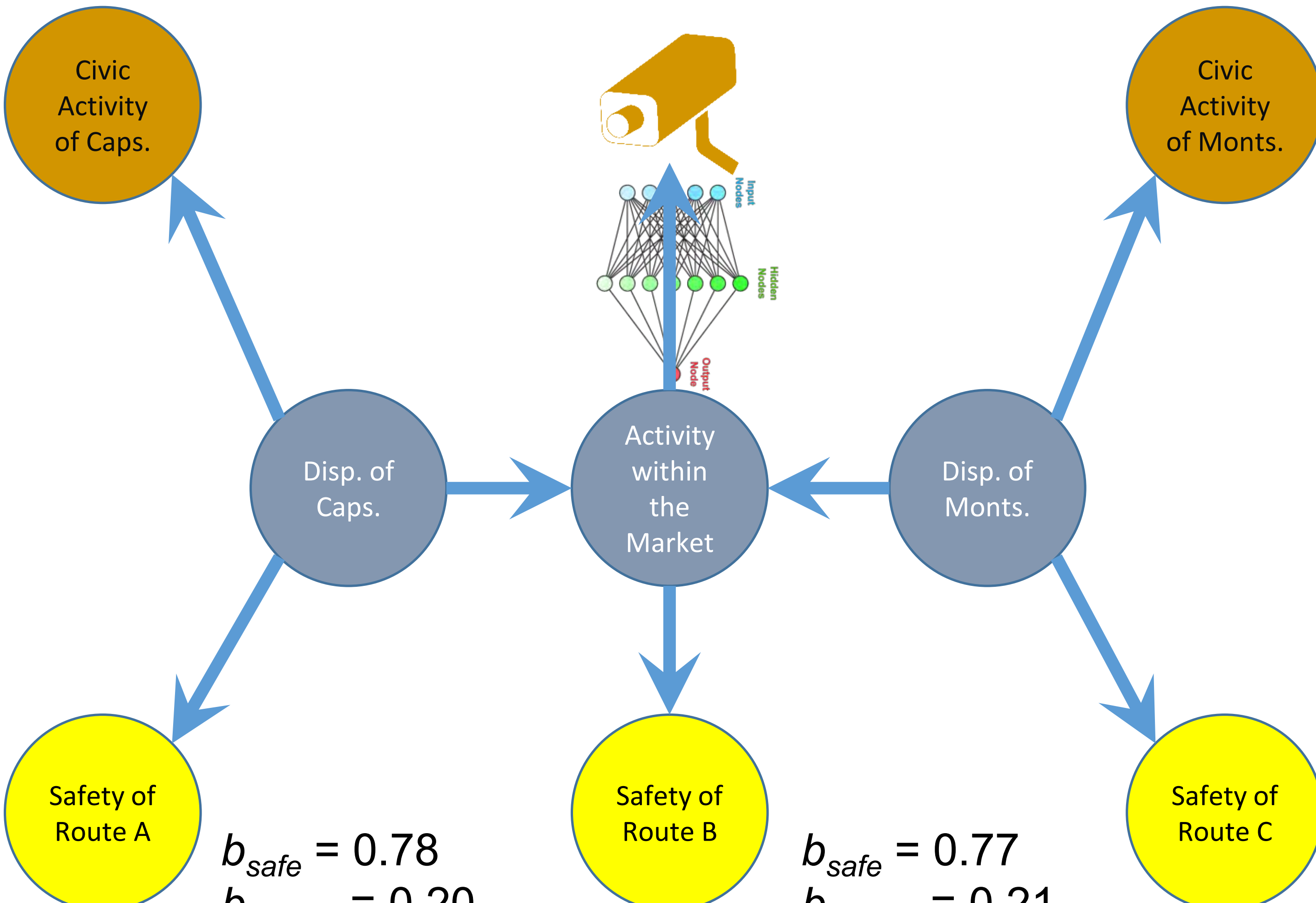




Trained on digits
but tested on letters

Sensoy, Kaplan, et al., submitted to NIPS 2018

ROUTE PLANNING EXAMPLE

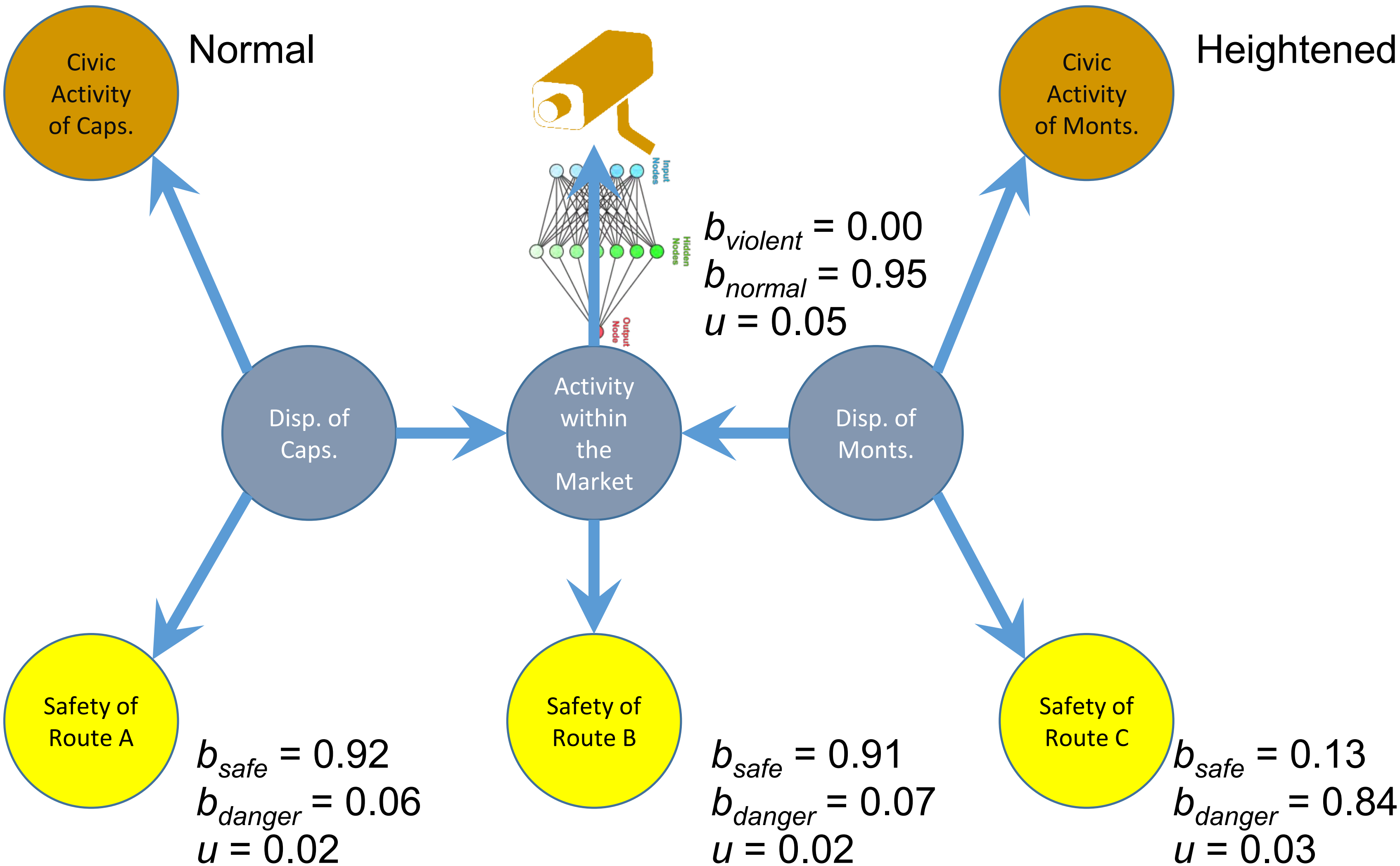


$b_{safe} = 0.78$
$b_{danger} = 0.20$
$u = 0.02$

$b_{safe} = 0.77$
$b_{danger} = 0.21$
$u = 0.02$

$b_{safe} = 0.21$
$b_{danger} = 0.77$
$u = 0.02$

ROUTE PLANNING EXAMPLE



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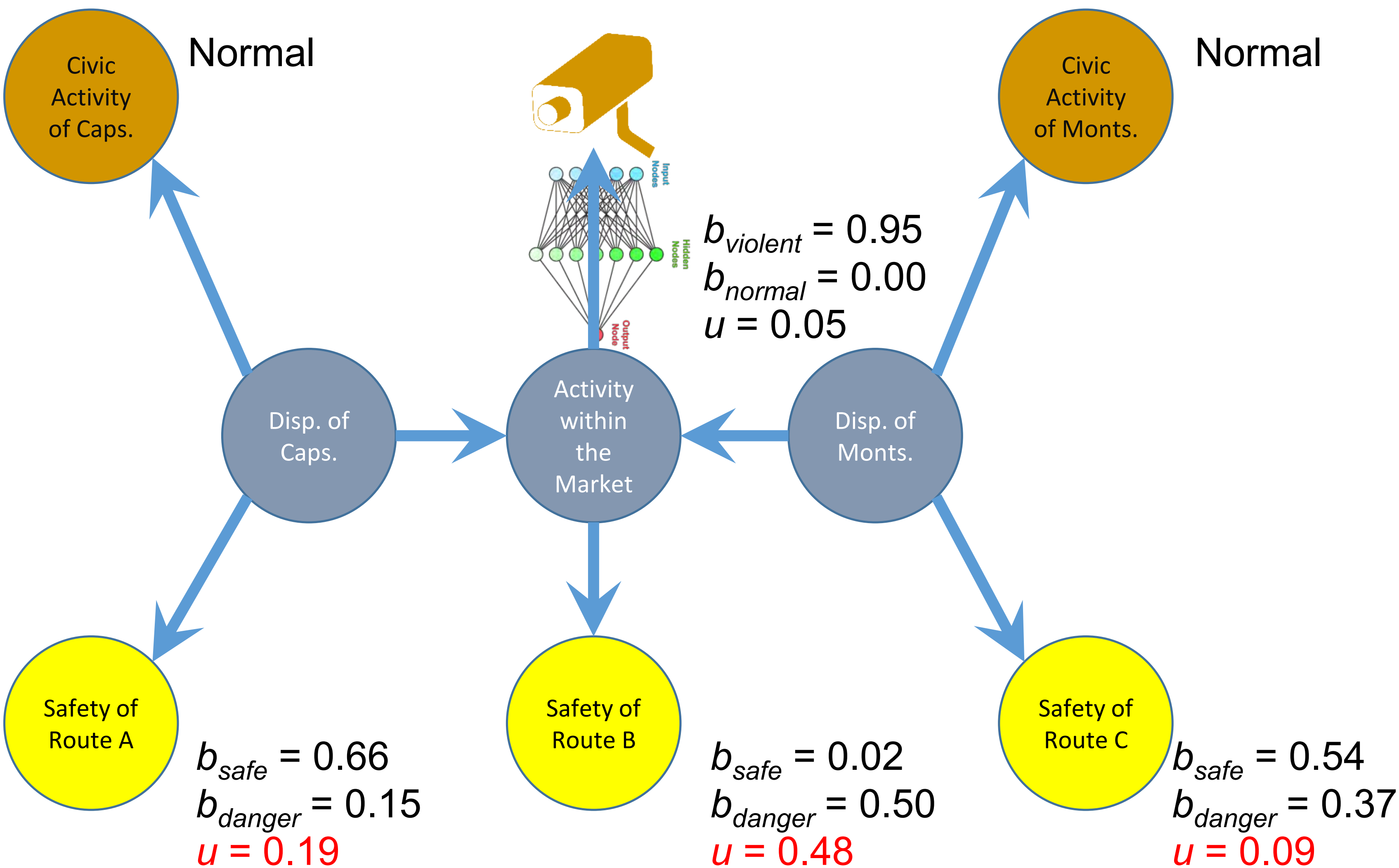

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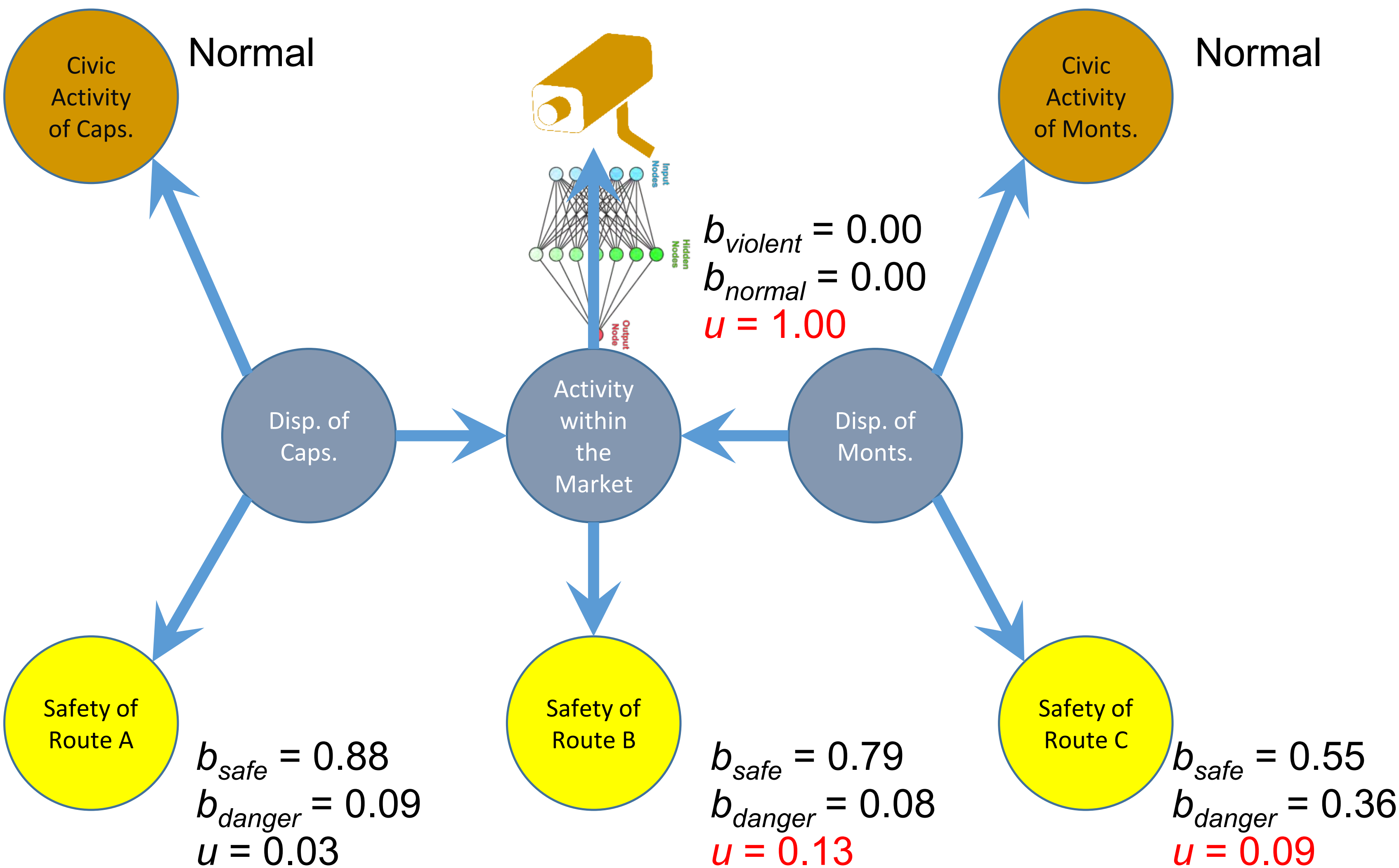

Panel: Machine Reasoning for Decision Support

Machine Reasoning for Determination of Threat Level in Irregular Warfare

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1867
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ARMY SCIENCE & TECHNOLOGY
SYMPOSIUM AND SHOWCASE
EMPOWERING A SOLDIER'S SUCCESS

August 21 – 23, 2018
Walter E. Washington Convention Center
Washington, DC

Irregular Warfare (IW)

Irregular warfare (IW) is defined as a violent struggle among state and non-state actors for legitimacy and influence over the relevant populations. IW favors indirect and asymmetric approaches, though it may employ the full range of military and other capabilities, in order to erode an adversary's power, influence, and will. It is inherently a protracted struggle that will test the resolve of our Nation and our strategic partners.

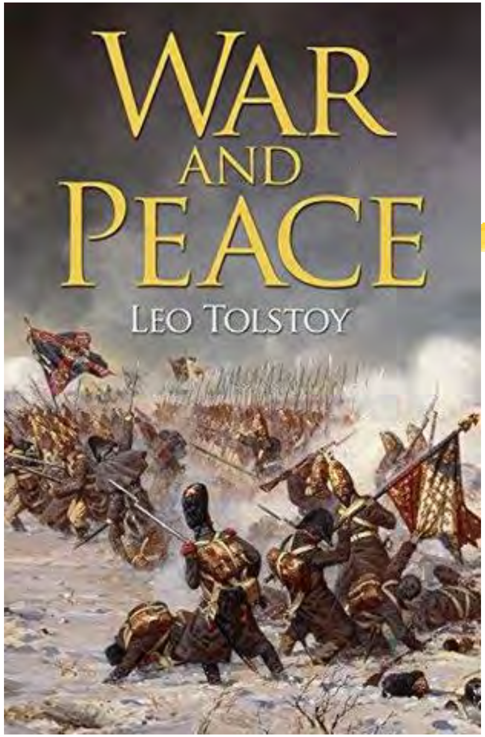
Irregular Warfare (IW)

Joint Operating Concept (JOC)

11 September 2007

- IW campaign depends on <u>military power</u> and (more on) <u>understanding of social dynamics</u>
- "People will be the key to IW success"*
- Social Dynamics
  - Tribal politics, social networks, religious influences, and cultural change

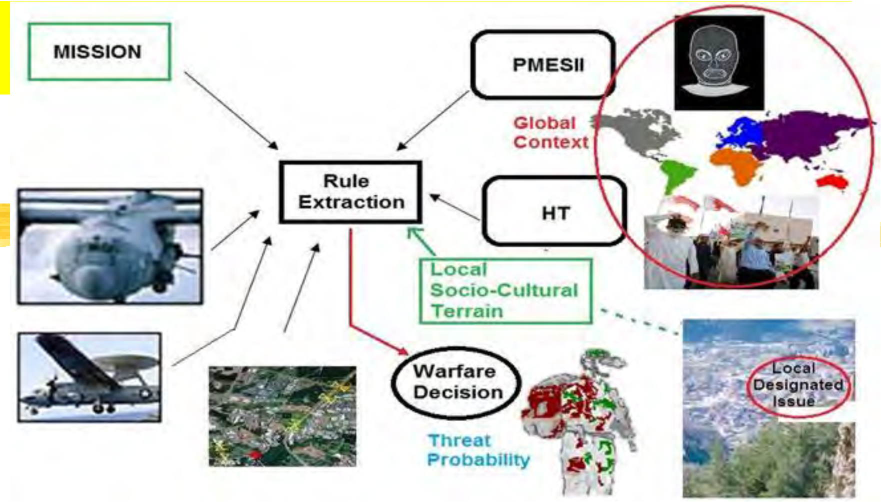
* Irregular War (IW) Joint Operation Concept (JOC)", version 1.0, 9/11/2007. Department of Defense



"Spirit of Army" and "Human Terrain"

- Retreat of Napoleon and French Army
- Sudden Russian partisan war and winning
- "A war was determined by the spirit of army not by mass nor by genius" Leo Tolstoy, War and Peace.
- Importance of people and human activities in field operation in IW and Counterinsurgency (COIN)
- "Sociocultural, political, psychological, collective behavior" → **Human Terrain**
- **Human Terrain**: In field operations, "the social, political, and economic environment, belief systems, and forms of interaction of the people among whom soldiers operate."*
- * A. M. de Vries, "The Human Terrain of Counterinsurgency Operations: Developing the Military Mindset and Social Science Support," Defense Science and Technology Laboratory, Wiltshire, UK, 2010.

Technical Approach



Objective:

- Development of <u>an irregular warfare decision assist system</u> for determining and predicting the operating environment threat level by utilizing diverse HT (human terrain) data of past and real-time transient socio-cultural events.

Benefits:

- Incorporation of the global perspective in to local decision making for irregular warfare in determining threat under diverse and transient social and military situations → Operational Benefit
- Answer to :"With the local populace info gathered by Sp Op, what is the insurgency/tribal uproar threat?

Approach

- Human-Like Reasoning → Inductive Reasoning
- Information Entropy based Algorithm for Applying inductive inference → machination → Update and Learning
- Extraction of dominant contributors (of high separability) toward Rule Generation with Prob and margin of error

Expectation, Surprise, Information, Entropy

- Information measure
  - Comparison of the contents of new data (evidence) with the prior state of expectation
  - The higher prior estimate of the probability for an outcome to occur, the lower will be the information gain by observing it to occur, and less "Surprise"
  - Information Quantity (I_Q) "Prior estimate of a probability (expectation)"

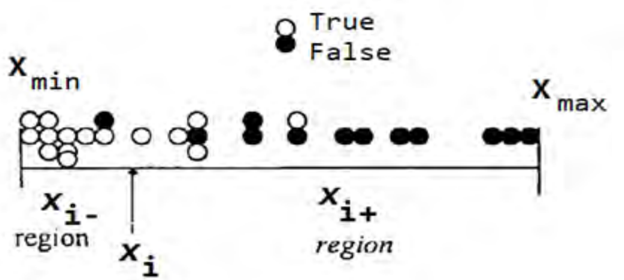
$$I_Q = -k \ln P$$

- Information Entropy: A measure of the "amount of uncertainty" in probability distribution → <u>Expected value of information gain</u>
- Claude Shannon:

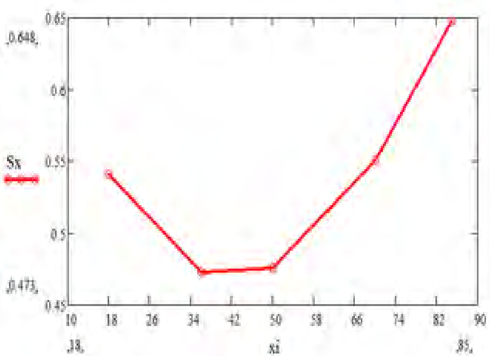
$$S = -k \sum_i P_i \ln P_i$$

Attribute Values and Conversion to Binary Values

- Analog Value Attributes
- Threshold value determination (for binary designation)
- Conditional Entropy and Entropy Minimization



$$x_{th} = \arg\min\{S(x_i) = p(x_{i-})S(x_{i-}) + p(x_{i+})S(x_{i+})\}$$



$S(x_{i-}) = -[p(T \mid x_{i-})\ln p(T \mid x_{i-}) + p(F \mid x_{i-})\ln p(F \mid x_{i-})]$: Conditional entropy for x_{i-}: $[X_{\min}, x_i]$ domain,

$S(x_{i+}) = -[p(T \mid x_{i+})\ln p(T \mid x_{i+}) + p(F \mid x_{i+})\ln p(F \mid x_{i+})]$: Conditional entropy for x_{i+}: $[x_i, X_{\max}]$

$p(x_{i-})$: is the ratio of the number of samples in the x_{i-}: $[X_{\min}, x_i]$ domain and the total number of samples,

$p(x_{i+})$is the ratio of the number of samples in the x_{i+}: $[x_i, X_{\max}]$ domain and the total number of samples,

$p(T \mid x_{i-})$: the ratio of the number of samples in x_{i-}: $[X_{\min}, x_i]$ domain which belongs to outcome T and the total number of samples in x_{i-}: $[X_{\min}, x_i]$ domain,

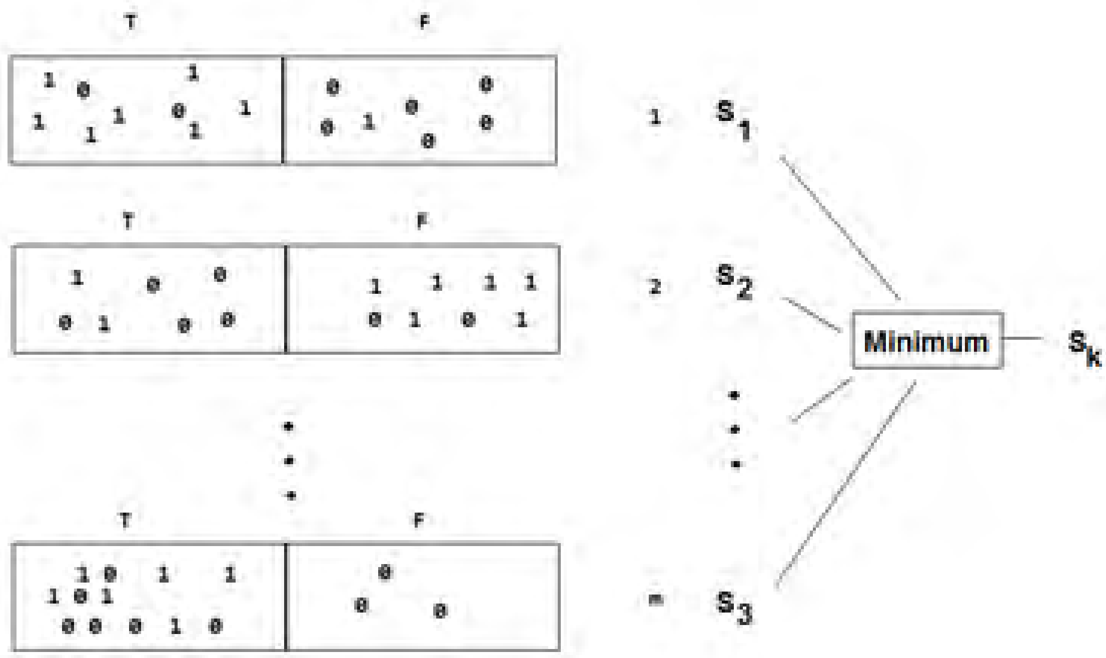
$p(F \mid x_{i-})$: the ratio of the number of samples in x_{i-}: $[X_{\min}, x_i]$ domain which belongs to outcome F and the total number of samples in x_{i-}: $[X_{\min}, x_i]$ domain,

Dominant Contributors – Order of Importance

$$S_{i1} = -[p_i(T|1)\ln p_i(T|1) + p_i(F|1)\ln p_i(F|1)]$$

$$S_{i0} = -[p_i(T|0)\ln p_i(T|0) + p_i(F|0)\ln p_i(F|0)]$$

$$S_i = p_i(0)S_{i0} + p_i(1)S_{i1}$$



$$S(x_i): \ \arg\min_x S(x)$$

Decision Rule with Dominant Contributors

- Prediction rule R_k for the k-th attribute
  - Highest conditional probability from

$$p_k(T\,|\,1),\; p_k(T\,|\,0),\; p_k(F\,|\,1),\; p_k(F\,|\,0)$$

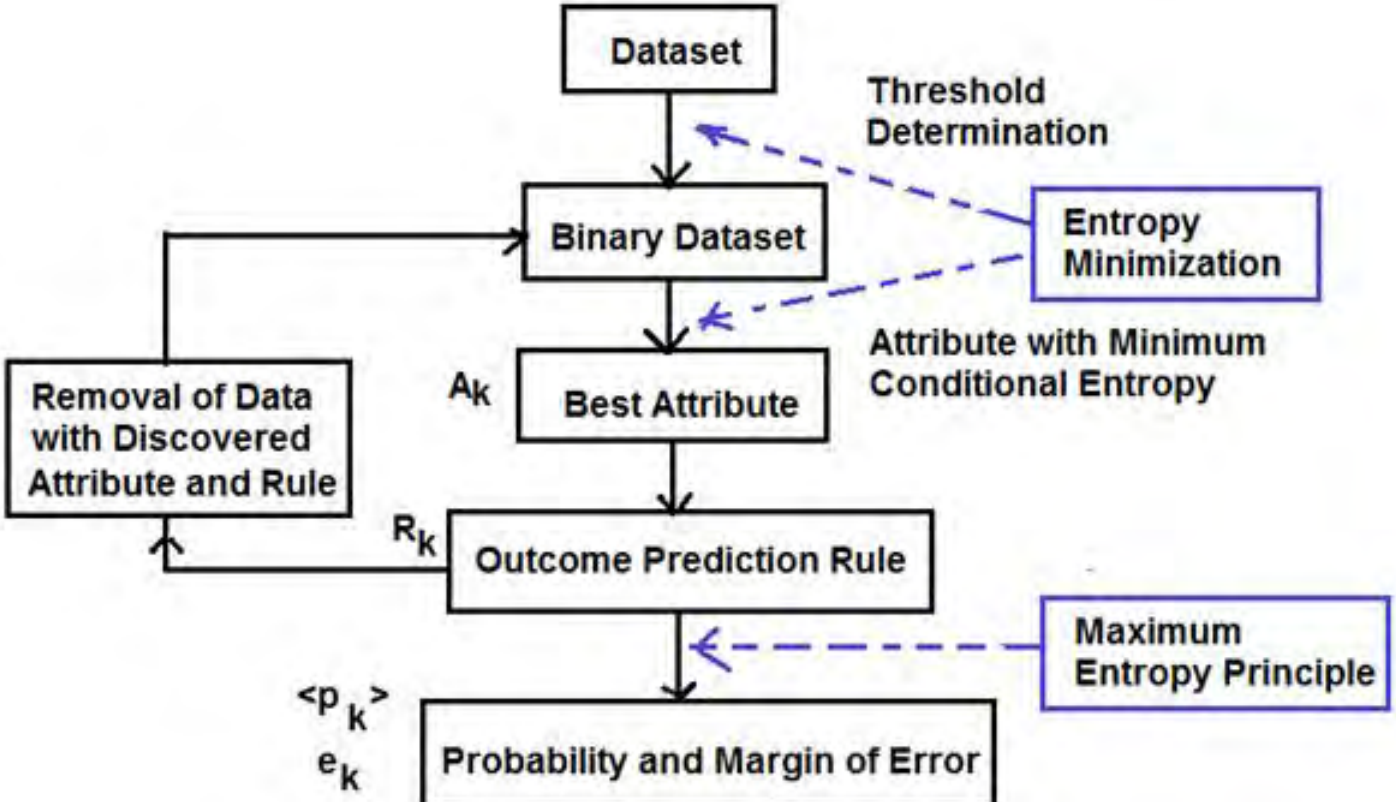
- Unbiased Probability <p> **(Bayesian Estimate) – "Laplace Rule of Succession"**
  - Maximum Entropy based
  - x_k: For k-th attribute, the total number of samples satisfying the <u>condition</u> and the <u>outcome</u> (event)
  - n_k: For k-th attribute, the total number of samples satisfying <u>only the condition</u>

$$< p_k(O) >= \frac{x_k + 1}{n_k + 2}$$

- Uncertainty or Margin of Error(e)
  - z: z-score (1.65 for 90% CI, 1.96 for 9 99%)

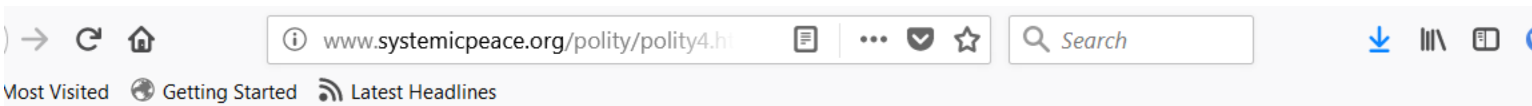
$$e_k(O) = z \cdot \frac{< p_k(O) > \cdot \{1 - < p_k(O) >\}}{n_k + 2}$$

Structure of Algorithm



Polity Data

- Lack of or No access to Real Data of Human Terrain
- Polity Database: Polity IV Project
  - Political Regime Characteristics and Transition
  - Sponsored by PITF (Political Instability Task Force)



Polity IV Individual Country Regime Trends, 1946-2013

PLEASE NOTE: The Center for Systemic Peace (CSP) Web site has been reorganized and refreshed. The Polity Project and INSCR Data pages have been moved; please click here to be taken to the new CSP Web site or on the logos at the bottom of the page to navigate to the new pages.

Annual Polity scores have been plotted for each of the 167 countries currently covered by the Polity IV data series for the period 1946-2013 (trend graphs are also included with the Polity IV 2010 Country Reports). This version of the Polity Country Trend graphs display periods of "factionalism" and important Polity change events, including autocratic backsliding, executive auto-coup or *autogolpe*, revolution, collapse of central authority (state failure), and successful military coups. Click on the country of interest in the "Regimes by Type 2013" map directly below (or table following) to view that country's contemporary regime trend (click here for a explanatory guide to the Polity Country Trend graphs)

Center for Systemic Peace

INSCR

Example 4 – Polity Data

Center for Systemic Peace INSCR

www.systemicpeace.org/inscrdata.html

Getting Started Latest Headlines

Polity IV: Regime Authority Characteristics and Transitions Datasets

User's Manual PDF	**Polity IV Annual Time-Series, 1800-2016**	**Polity IV Project, Political Regime Characteristics and Transitions, 1800-2016**, annual, cross-national, time-series and polity-case formats coding democratic and autocratic "patterns of authority" and regime changes in all independent countries with total population greater than 500,000 in 2016 (167 countries in 2016) (SPSS and Excel data; PDF codebook) Click here for the list of changes made during the year 2016 annual data update (SPSS and Excel file; PDF codebook).	SPSS Series	Excel Series
	Polity IVd Polity-Case Format, 1800-2016		SPSS Case	Excel Case

1.0* **PRESENT** Present Polity (p4d)
1.1 **CYEAR** Country Year (p4)
1.2 **CCODE** Numeric Country Code
1.3 **SCODE** Alpha Country Code
1.4 **COUNTRY** Alpha Country Name
1.5 **YEAR** Year Coded (p4)
1.6 **FLAG** Tentative Coding (p4)
1.7 **FRAGMENT** Polity Fragmentation (p4)

3.1 **XRREG** Regulation of Chief Executive Recruitment
3.2 **XRCOMP** Competitiveness of Executive Recruitment
3.3 **XROPEN** Openness of Executive Recruitment
The Independence of Executive Authority.........
3.4 **XCONST** Executive Constraints (Decision Rules)
Political Competition and Opposition.........
3.5 **PARREG** Regulation of Participation
3.6 **PARCOMP** The Competitiveness of Participation

2.1 **DEMOC** Institutionalized Democracy
2.2 **AUTOC** Institutionalized Autocracy
2.3 **POLITY** Combined Polity Score
2.4 **POLITY2** Revised Combined Polity Score (p4)
2.5 **DURABLE** Regime Durability (p4)
2.6* **PERSIST** Number of Years Polity Has Persisted (p4d)

4.1 **PRIOR** Prior Polity Code (p4)
4.2 **EMONTH** Polity End Month
4.3 **EDAY** Polity End Day
4.4 **EYEAR** Polity End Year
4.5 **EPREC** End Date Precision
4.6 **INTERIM** Interim Polity Code (p4)
4.7 **BMONTH** Polity Begin Month
4.8 **BDAY** Polity Begin Day
4.9 **BYEAR** Polity Begin Year
4.10 **BPREC** Begin Date Precision
4.11 **POST** Post Polity Code (p4)
4.12 **CHANGE** Total change in POLITY value (p4)
4.13 **D4** Regime Transition Completed (p4)
4.14 **SF** State Failure (p4)
4.15 **REGTRANS** Regime Transition (p4)

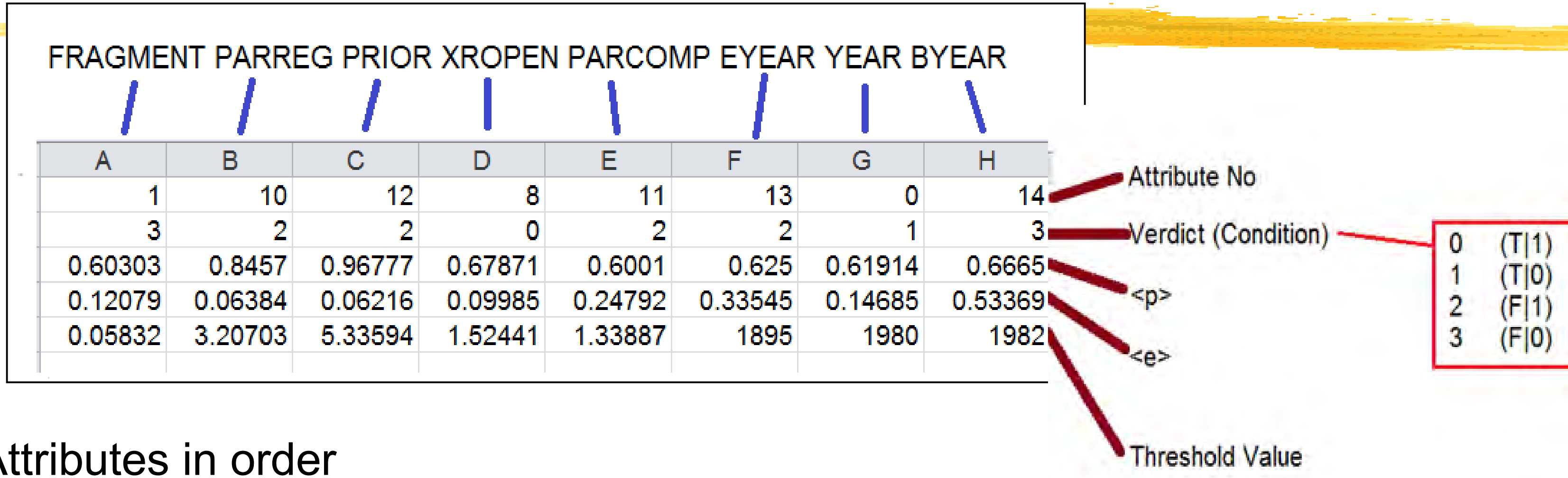
3 2 1 0 -1 -2

Toward Democracy ← → Toward Authoritarian

- For Testing
- **16 Attributes**
- 1 Classification (RegTrans)
- 1369 Samples
- Randomly divided to 4 sub-samples of almost equal size
  - A, B, C, and D
- (1) Train by A & Test by BCD subset
- (2) Train by AB & Test by CD subset

Polity Data

- Train by A (387 samples) and Test by BCD (1081 samples)
- RULE



FRAGMENT	PARREG	PRIOR	XROPEN	PARCOMP	EYEAR	YEAR	BYEAR
A	B	C	D	E	F	G	H
1	10	12	8	11	13	0	14
3	2	2	0	2	2	1	3
0.60303	0.8457	0.96777	0.67871	0.6001	0.625	0.61914	0.6665
0.12079	0.06384	0.06216	0.09985	0.24792	0.33545	0.14685	0.53369
0.05832	3.20703	5.33594	1.52441	1.33887	1895	1980	1982

- 8 Attributes in order
- Correct (66.51%)
  - True Positive (19.00 %)
  - True Negative (47.51 %)
- Incorrect (33.49 %)
  - False Positive (15.71 %)
  - False Negative (17.78 %)

Polity Data

- Train by AB (749 samples) and Test by CD (719 samples)
- RULE

FRAGMENT	PARREG	XRCONST	XROPEN	PARCOMP	EYEAR	YEAR	CHANGE	
A	B	C	D	E	F	G	H	
1	10	12	8	11	13	0	16	Attribute No
3	2	1	0	2	3	0	1	Verdict (Condition)
0.68652	0.8335	0.57129	0.60986	0.58057	0.53857	0.92871	0.52002	<p>
0.08368	0.04901	0.12964	0.07581	0.17371	0.271	0.13477	0.1131	<e>
0.05798	3.18555	5.37109	1.52344	1.34082	1979	1978	4.32812	Threshold Value

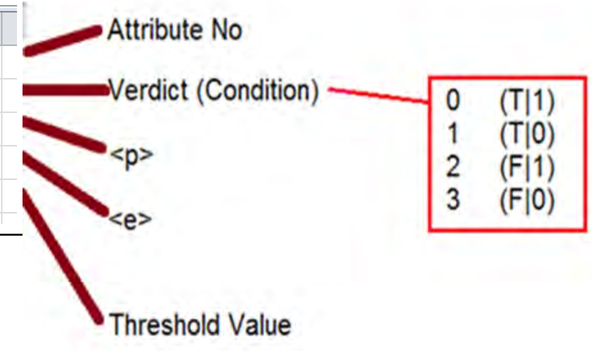
0	(T|1)
1	(T|0)
2	(F|1)
3	(F|0)

- 8 Attributes in order
- Correct (64.12%)
  - True Positive (27.82 %)
  - True Negative (36.30 %)
- Incorrect (35.88 %)
  - False Positive (24.48 %)
  - False Negative (11.40 %)

Polity Data

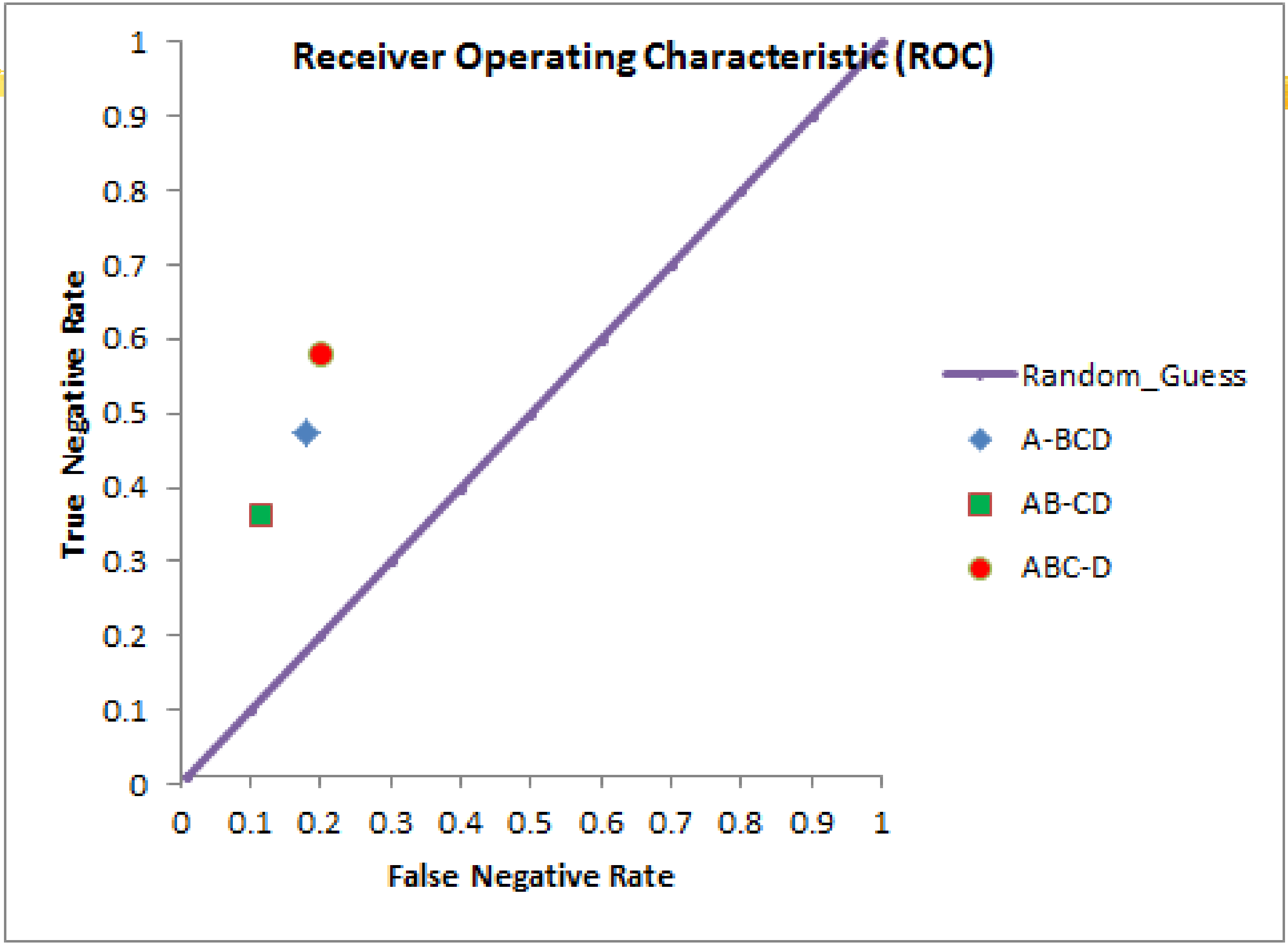
- Train by ABC (1121 samples) and Test by D (347 samples)
- RULE

FRAGMENT	AUTOC	PRIOR	EYEAR	CHANGE	YEAR
A	B	C	D	E	F
1	3	12	13	16	0
3	2	2	3	1	3
0.72217	0.86816	0.88867	0.5332	0.60645	0.6665
0.06543	0.03714	0.05307	0.25244	0.08667	0.53369
0.05591	4.85547	3.13867	1967	4.27734	2004



  - 6 Attributes in order
  - Correct (71.07 %)
    - True Positive (13.21%)
    - True Negative (57.86 %)
  - Incorrect (28.93 %)
    - False Positive (8.8 %)
    - False Negative (20.13 %)
- Fewer Number of Attributes
- Accuracy Improved
- <p> raised and <e> lowered

Polity Data – ROC (Receiver Operating Characteristic)



Conclusions

- Machine Reasoning Prototype Implementation
- Dominant Contributor Extraction ("High Separability")→ Data Size Reduction
- Rule Extraction with Quantified Probability and Margin of Error
- Update with New Data and Decision Experience (Success or Failure)
- Theoretical Rigor in Data Analytics
- Other Application Areas
  - Behavioral Security for cybersecurity enhancement or lapse
    - Insider Threat Detection
  - Radicalization Detection
    - When do people snap?

Acknowledgment

- Acknowledgment
  - #DO1-W911SR-14-2-0001-0015 “Irregular Warfare Decision Assist System for Determining Threat” 8/1/2017 – 7/31/2019 (funded period)
  - U. S. Department of Army through MSRDC
  - POC: Raymond McGowan, CIV USARMY RDECOM

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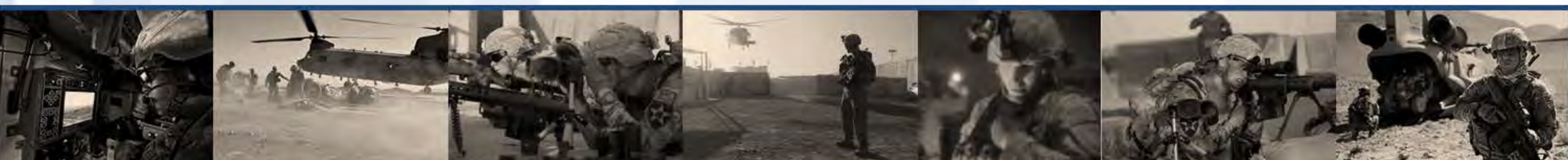
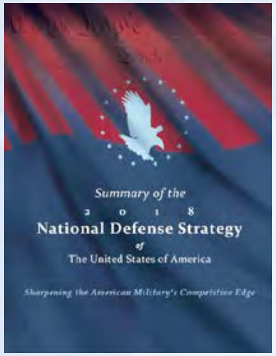
Army Science & Technology Overview

Dr. Thomas Russell
Deputy Assistant Secretary of the Army
(Research & Technology)

21 August 2018



Army S&T Strategy



Army Modernization Strategy

Army Modernization Priorities

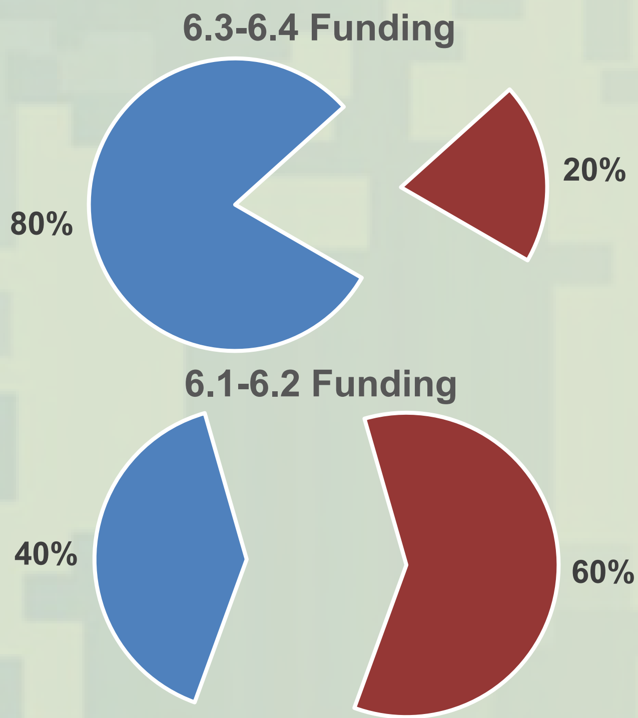
1. Long Range Precision Fires
2. Next Generation Combat Vehicle
3. Future Vertical Lift
4. Network/C3I
5. Air & Missile Defense
6. Soldier Lethality

Army S&T Strategy

Army S&T Investment Strategy

S&T Projects Aligned to Modernization Priorities

S&T Projects directly aligned to provide technology options for the Army's Modernization Priorities.



Exploration & Innovation

Science & Technology efforts aimed at exploration, discovery, and innovation supporting next generation Army capabilities in the mid- and far-term.

The Urgency of Modernization

The Army's Mission remains constant: To deploy, fight, and win our Nation's wars by providing ready, prompt, and sustained land dominance by Army forces across the full spectrum of conflict as part of the Joint Force.

The 2017 *National Security Strategy* (NSS) and 2018 *National Defense Strategy* (NDS) call for the Army to become more lethal across all domains in order to deter and defeat near-peer adversaries.

A combination of strategic, technological, and institutional trends now places the Army's competitive advantages at risk.

- ❑ Army's focus on ongoing conflicts combined with reality of constrained resources to slow, defer, and/or halt the development of new capabilities.
- ❑ Adversaries have invested in capabilities to provide overmatch across multiple domains.
- ❑ Army is not institutionally organized to quickly deliver modern, critical capabilities to Soldiers and combat formations.

Inflection Point: The Army can no longer afford to defer modernization without risk of losing overmatch.

Vision of the Future Army in 2028

The Army of 2028 will be ready to deploy, fight, and win decisively against any adversary, anytime, and anywhere, in a joint, multi-domain, high-intensity conflict, while simultaneously deterring others and maintaining its ability to conduct irregular warfare.

Secretary Mark Esper, AUSA, MAR 2018*

The Army will do this through:

- ❑ Employment of modern manned and unmanned ground combat vehicles, aircraft, sustainment systems, and weapons.
- ❑ Coupling them with robust combined arms formations and tactics based on modern warfighting doctrine.
- ❑ Centering on exceptional Leaders and Soldiers of unmatched lethality.

By investing in the Army's Six Modernization Priorities:

Long Range Precision Fires	***Army Network***
Next Generation of Combat Vehicles	***Air and Missile Defense***
Future Vertical Lift	***Soldier Lethality***

Technologies with leading edge potential that support these priorities include:
Artificial Intelligence (AI), ultra-secure communications, robotics, virtual reality, the internet of things, energetics, Directed Energy (DE), and ultra-designed materials.

Army S&T Investments by Priority

PB19 - $13.7B (FY19-23)

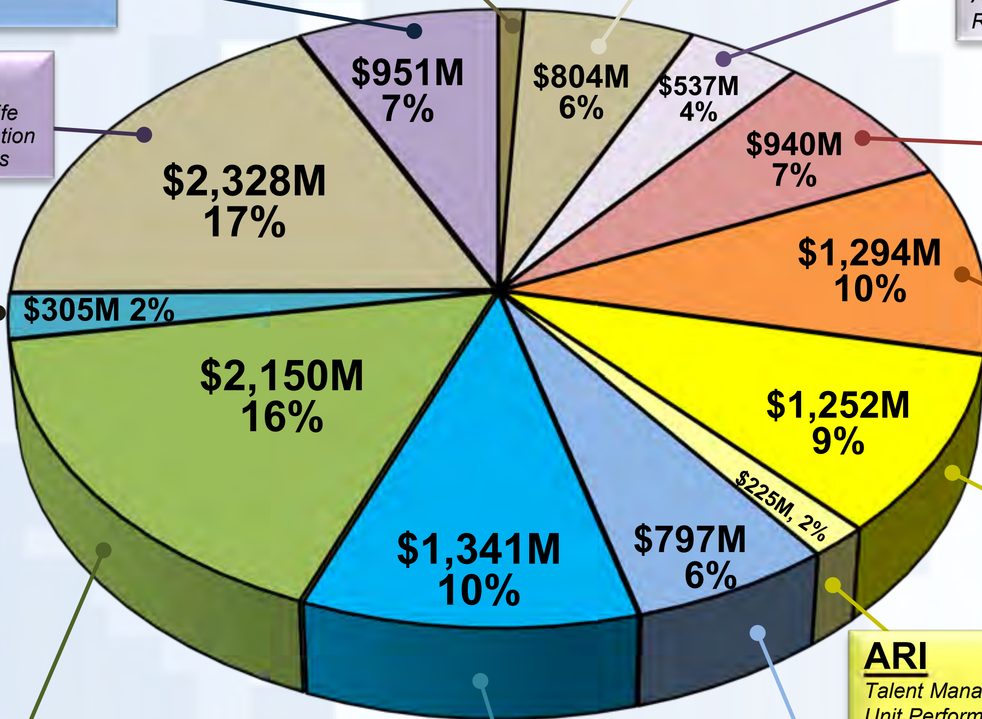
Management Support
Classified; Technical Information Activities
$116M, 1%

Maturation
Technology Maturation Initiatives; Manufacturing Technology

Air and Missile Defense
Smaller & Cheaper Missiles
High Energy Lasers
Gun Based C-Tactical & Small UAS
Advanced Seekers
Advanced Energetics & Propulsion
Radars

HPCMP
High Performance Modernization Program (DoD)

Basic Research
Materials Science; Medical/Life Sciences; Quantum / Information Science; Autonomy; Networks



Long Range Precison Fires
Propulsion for Extended Range Missiles
Extended Range Cannon Artillery
Enhanced Guidance / Navigation for Weapons
Advanced Energetics
Advanced Warheads for Cluster Munitions
Radars

Enabling
Anti-Tamper
Atmospheric Modeling
Logistics Planning R&D
Structural Hardening
Breaching Technologies
Components
Maneuver in Complex Environments

Network/C3I
Tactical Communications
Mission Command
Cyber Electromagnetic Activities
Assured Position, Navigation & Timing
Persistent ISR

Soldier/Lethality
Soldier & Squad Weapons
Training
Soldier Protective Equip
Situational Awareness
Physical/Cognitive Performance
Prolonged Field Medical Care

ARI
Talent Management
Unit Performance and Cohesion
Integrated Assessments

Next Generation Combat Vehicle
Next Gen Combat Vehicles Design
Vehicle Protection Against Advanced Threats
Advanced Power Generation and Distribution
AI, Robotics and Autonomy for Logistics & Combat Ops
Advanced Energetics & Direct Fire Weapons Systems

Future Vertical Lift
Platform Development and Demonstration
Next Generation Unmanned Aircraft System Technologies
Aviation Protection / Aircraft Survivability
Situational Awareness
Integrated Mission Systems
Advanced Power Systems

Medical
Combat Casualty Care, Infectious Disease mitigation, clinical/rehabilitative medicine

Army Investments	FY19-23
BA1	$2,328M
BA2	$4,767M
BA3	$5,290M
BA4	$522M
BA7	$301M

BA6 $155M, Procurement $350M

Version: 26 Jan 2018

Long Range Precision Fires

Goal: Provide extended range allowing an increased capability to support maneuver and counter enemy long-range systems.

Lines of Effort

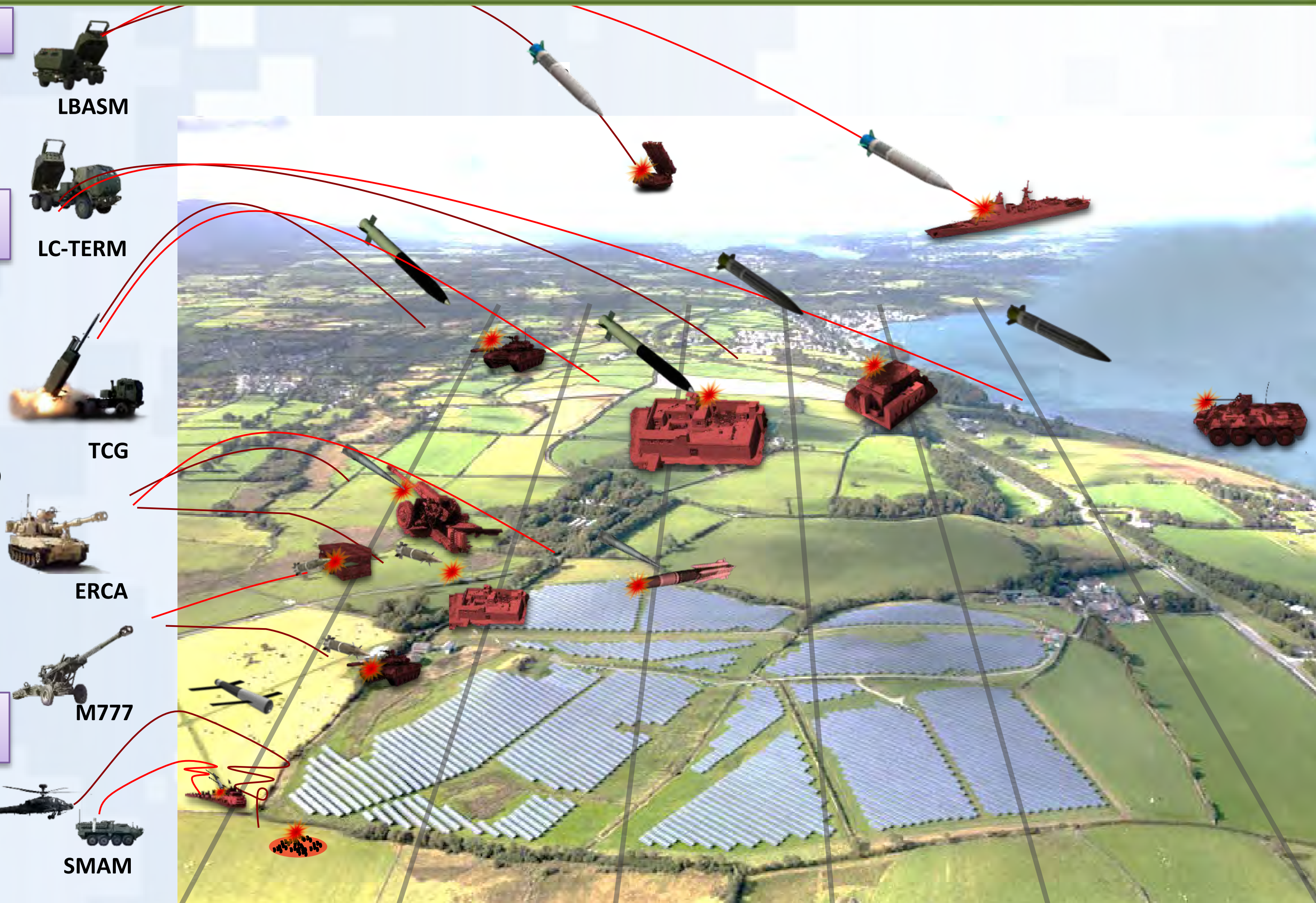
- Deep Fires
- Close Fires
- Foundational

Technology Demonstrations

- Land-Based Anti- Ship Missile (LBASM)
- Single Multi-mission Attack Missile (SMAM)
- Multiple Simultaneous Engagement Technologies (MSET)
- Extended Range Cannon Artillery (ERCA)
- Low Cost – Tactical Extended Range Missile
- Cluster Munition Replacement Technologies
- Long Range Maneuverable Fires (LRMF)

Critical Technology Areas

- Extend Range
- Expand Coverage
- Enable Cross-domain Maneuver



Next Generation Combat Vehicle

Goal: Engage in close combat and deliver decisive lethality during the execution of combined arms maneuver.

.

Lines of Effort

- Robotics & Autonomous Systems
- Ground Vehicle Platforms
- Armor & Active Protection
- Kinetic & Laser Lethality Effects

Technology Demonstrations

- Combat Vehicle Robotics (CoVeR)
- Robotics for Engineer Operations
- Ground System Active Defense (GSAD)
- Advanced Powertrain Demonstrator
- Advanced Lethality & Accuracy System for Medium Caliber (ALAS-MC)
- Extended Line of Sight (ELoS)

Critical Technology Areas

- Maneuver Robotics and Autonomous Systems
- Directed Energy & Energetics
- Power Generation & Management
- Advanced Armor
- Vehicle Protection Suites

Advancing Ground Capability to Enable Joint Combined Arms Maneuver

Future Vertical Lift

Goal: Close selected Army capability gaps and rapidly deliver 5th Gen rotorcraft to the Army.

Lines of Effort

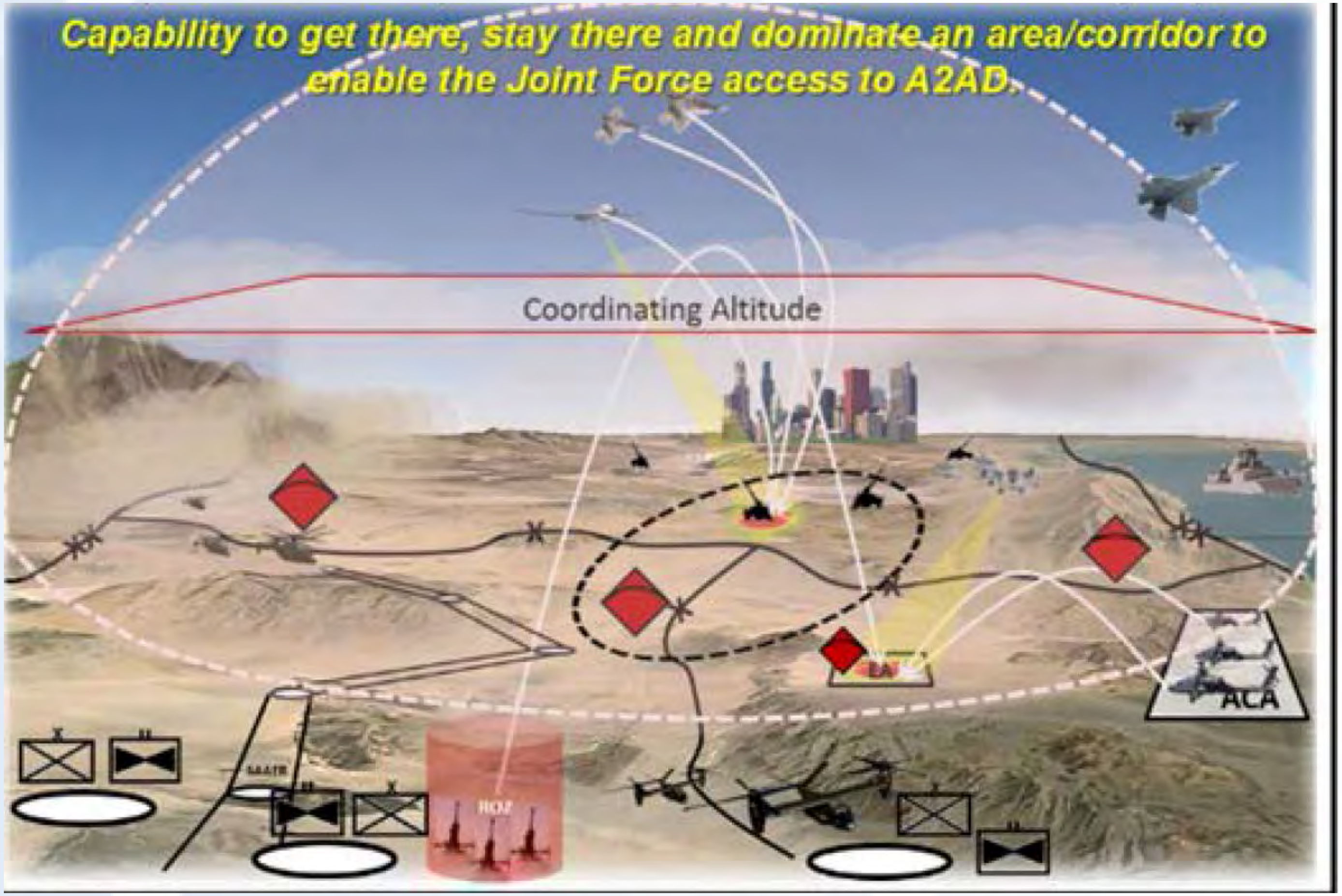
- FVL Capability Set 1
- Modular Open Systems Approach
- Future Unmanned Aircraft System
- FVL Capability Set 3

Technology Demonstrations

- Joint Multi-Role Technology Demonstrator
- Degraded Visual Environment-Mitigation
- Next Generation Tactical UAS Tech Demonstrator
- Alternative Concept Engine
- Next Gen Rotorcraft Transmission
- Integrated Mission Equipment
- Modular Missile Technology
- Multi-Role Small Guided Missile
- Advanced Rotorcraft Armaments Protection System

Critical Technology Areas

- Expanded Reach & Protection during Movement of Forces
- Increased payload, maneuverability and performance
- Manned-Unmanned Teaming



Network/C3I

Goal: Provide Soldier with assured communications in contested environments through situationally-aware, intelligent network, and autonomously routing of information over resilient communications link.

Lines of Effort

- Unified Network
- Common Operating Environment
- Command Post
- Core Competencies
- PNT – Enterprise Enabler
- PNT – Ground User Equipment

Technology Demonstrations

- Modular RF
- Non-Traditional Waveforms
- Protected SATCOM
- WGS Interference Cancellation
- Spectrum Obfuscation
- Next Gen HF
- Every Receiver a Sensor
- Robust Grey C3I
- Integrated Demos with NGCV, Soldier Lethality, FVL, AMD, and LRPF

Critical Technology Areas

- Tactical Network/Comms
- CEMA/EW/Cyber
- Mission Command/Command Posts
- A-PNT
- Persistent ISR

Air and Missile Defense

Goal: Provide capability to defend against enemy air attack at extended range.

Lines of Effort

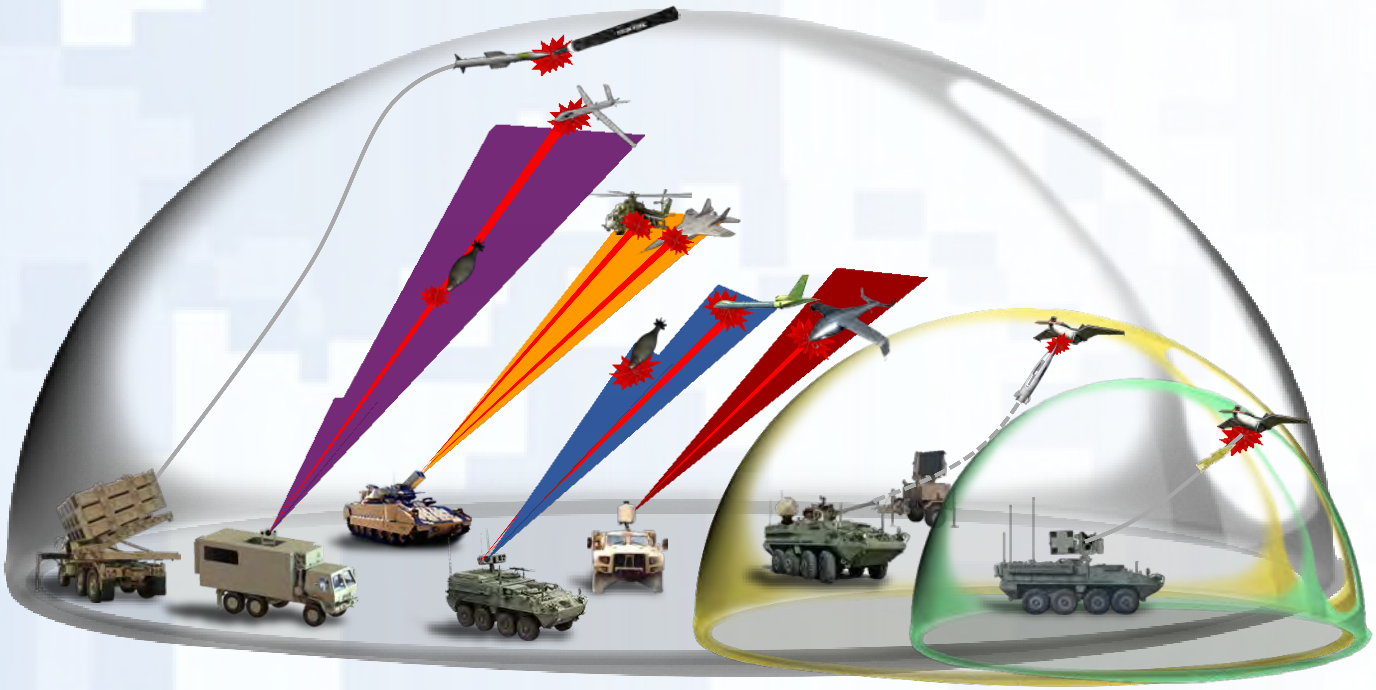
- Indirect Fire Protection Capability
- Maneuver – Short Range Air Defense
- Sensors & Other Efforts

Technology Demonstrations

- Low Cost Extended Range Air Defense (LowER AD)
- Maneuver AD Technologies (MADT)
- Ballistic Low Altitude Drone Engagement (BLADE)
- Accurate Rapid Controlled Hybrid Effects Round (ARCHER)
- High Energy Laser Tactical Vehicle Demonstrator (HEL TVD)
- Multi-Mission High Energy Laser (MMHEL)
- Unconventional Countermeasures & Survivability

Critical Technology Areas

- Mobile and Survivable Maneuver Short Range Air Defense (M-SHORAD)
- Counter UAS
- Operate within a Contested Environment



Soldier Lethality

Goal: Improve Soldier and small unit performance, reduce surprise, increase protection, and enhance lethality in close combat on an intensely lethal and distributed battlefield and within complex, urban terrains.

Lines of Effort

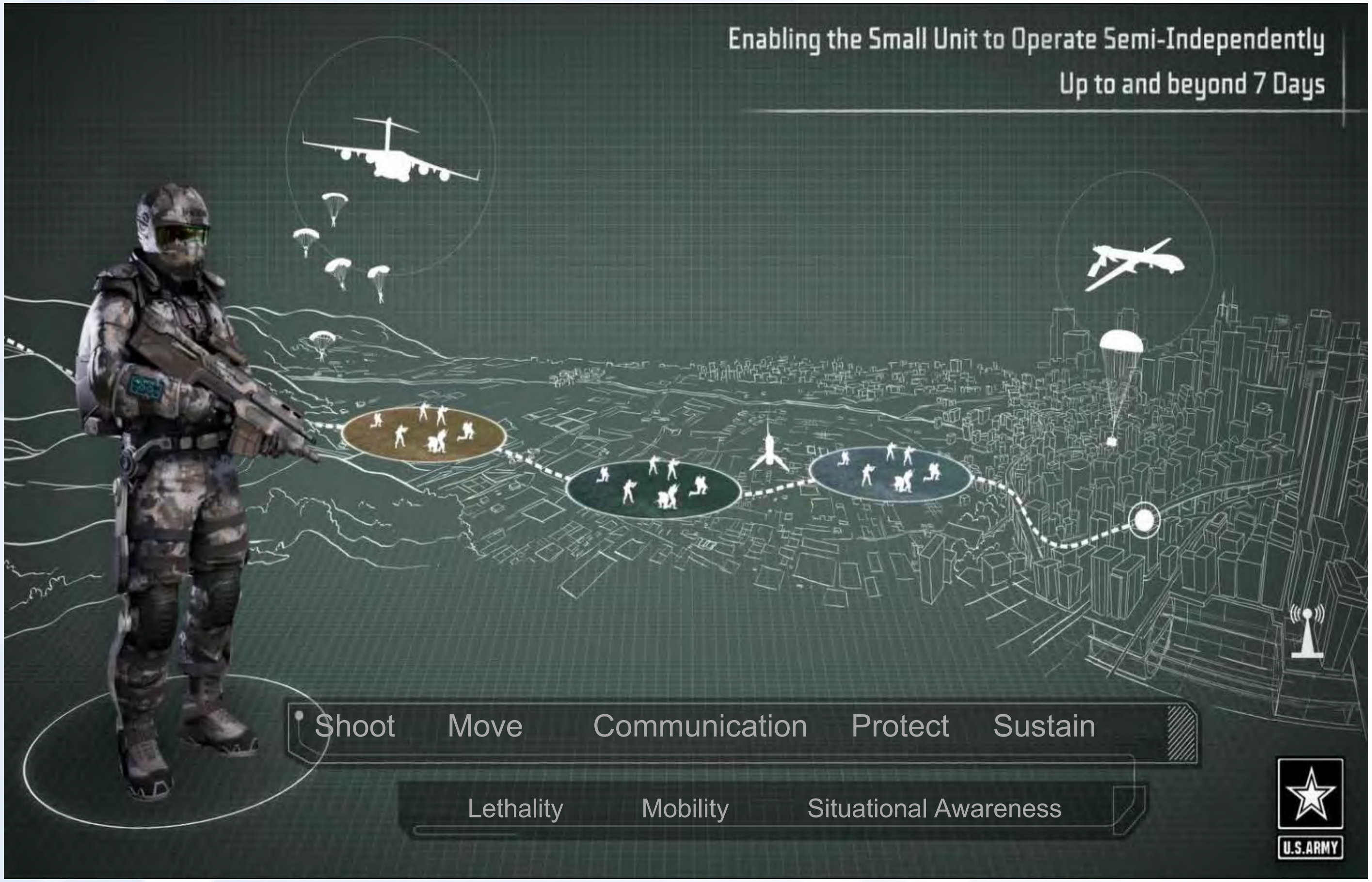
- Next Generation Squad Weapon
- Enhanced Night Vision Goggle-Binocular
- Adaptive Soldier Architecture
- Synthetic Training Environment
- Personnel Research
- Core Competencies

Technology Demonstrations

- Next Gen Squad Weapons Technology
- Next Generation Family of Ammunition
- Soldier Signature Management
- Extreme Austere Environmental Protection
- Integrated Headborne Systems
- Body Armor
- Common Synthetic Environment
- Exoskeleton Systems

Critical Technology Areas

- Next Generation Squad Weapons and Ammunition
- Enhanced Body Armor
- Improved Soldier and Small Unit Performance
- Reduce the Soldier's Load and Increase Bearing Capacity



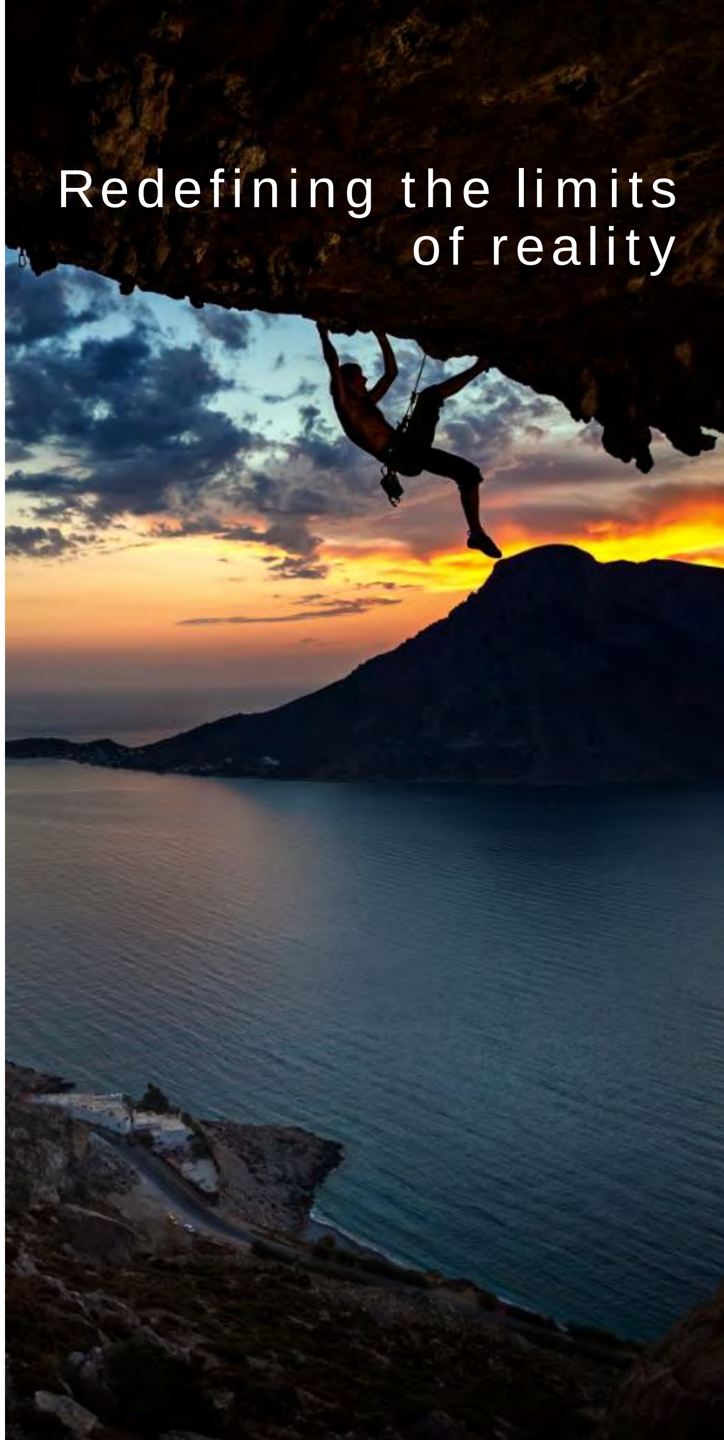
Summary

- The Army S&T strategy supports the Army Modernization Strategy, and ultimately the National Defense Strategy
- The strategy balances S&T investments in support of the Army's Modernization Priorities with investments in Exploration and Innovation for the next generation of Capability
- Army S&T has undertaken a series of initiatives to implement this strategy, restore portfolio balance, and ensure transition of technologies in support of the Army's Modernization Priorities

Questions?

Immersive Technologies:
The Future of Information Portrayal for Ground Soldiers

Real-time Immersive Audio for Realistic Training



Dave Fluegeman, VP, Simulation
Thomas Huisman, Product Manager

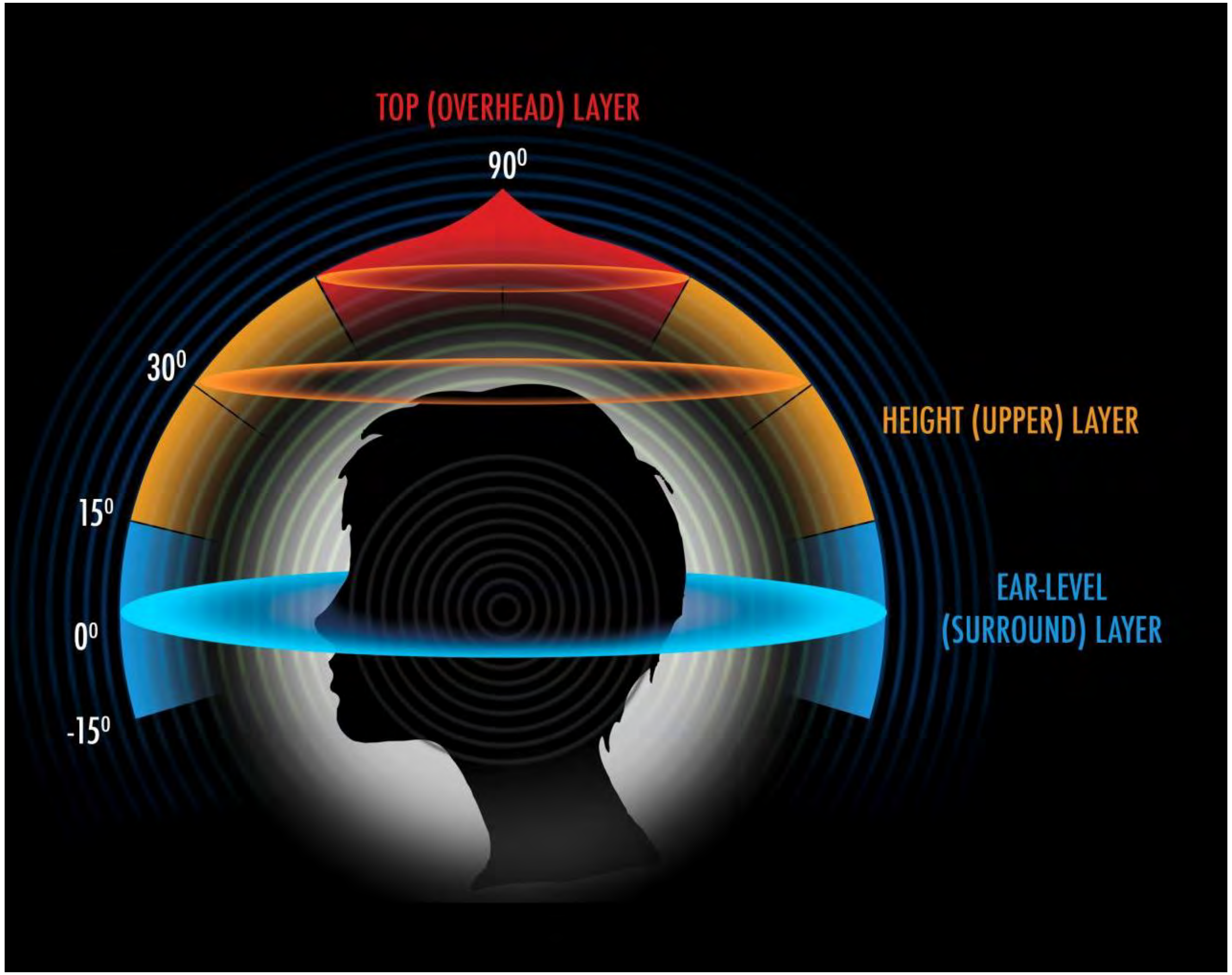
22 August, 2018

BARCO

Introducing *Object-based, Real-time* Audio Processing

Object-based sound means:

- It positions sound correctly relative to the trainee's position and object's behavior in 3D space (x,y,z).
- No sweet spot.
- Independent of speaker setup.




Grand
Central
Smith

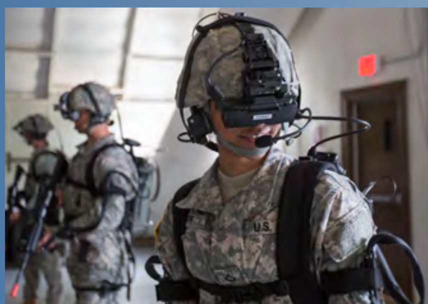







ARL

Congressionally Directed Medical Research Programs
CDMRP
Department of Defense



TRAINING and SIM

- Flight simulators
- HUD
- Emergency simulation
- Drone training
- Tactical training
- Psyops
- Hand-eye coordination
- Target practice
- Battlefield simulation

TEMPLE UNIVERSITY

U.S. Department of Veterans Affairs

HEALTH and REHAB

- Assessment
  - Visuo-vest
  - Oculomotor
  - Balance
  - Cognition
- Treatment
  - PTSD
  - TBI
  - Pain
  - Fear/Phobia

SCIENTIFIC INQUIRY

- Visual-perceptual
- Decision-making
- Neural correlates
- Oculomotor
- Cybersickness
- Integrated systems
  - VOG
  - EEG
  - HMD

Soldier Borne Power Generation In Tier 1 Environments

Noel Soto

21 August 2018

US ARMY NATICK SOLDIER RESEARCH, DEVELOPMENT & ENGINEERING CENTER

“When you are short of everything but the enemy, you’re in combat”

MLoC

Challenges

- Soldiers will be used for missions of longer duration and will be more isolated from supply lines
- Soldiers today use more technology to act as force multipliers
- The trend is to use more electronics
- Capabilities = Batteries = Weight Burden = Ineffective Soldiers

Battery Types

- Primary Batteries
  - Pro
    - Higher energy density allows for longer running time of equipment (120-300 Wh/Kg)
    - Less expensive
  - Con
    - Cannot be recharged
- Rechargeable Batteries
  - Pro
    - Rechargeable. (200+ recharging cycles)
    - Long term costs are reduced
  - Con
    - Energy density is lower (80-125 Wh/Kg)
    - Initial cost is high
    - Requires recharging capabilities

Recharging Batteries

- Fossil fuels
- Clean technologies
- Harvesting

Fossil Fuels

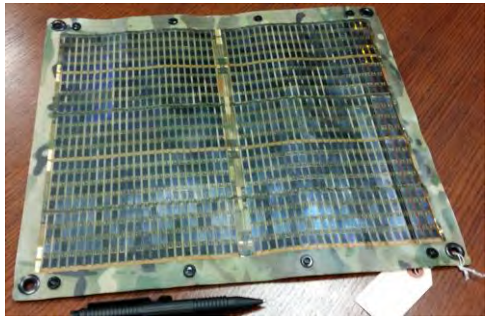
- Pro
  - High energy density (1 kW)
  - Low exertion from user
  - Low cost
- Con
  - Fuel logistics
  - Weight
  - Noise
  - Smell

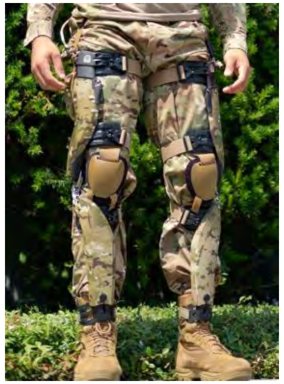
Clean Technologies

- Solar
  - Pro
    - Lightweight
    - Silent
    - Power (c. 50 W/m^2)
  - Con
    - Not rugged
    - Time/weather limited
    - Signature
    - Cost
- Fuel Cells
  - Pro
    - Steady power (10-50 W)
    - Silent
    - Clean waste
  - Con
    - Cost
    - Fuel logistics
    - Weight

Harvesting Technologies

- Solar
  - Pro
    - Lightweight
    - Power (c. 130 W/m^2)
  - Con
    - Not rugged
    - Cost
- Kinetic
  - Pro
    - Lightweight
    - Power availability
  - Con
    - Low to medium noise
    - Effort required
    - Acceptability



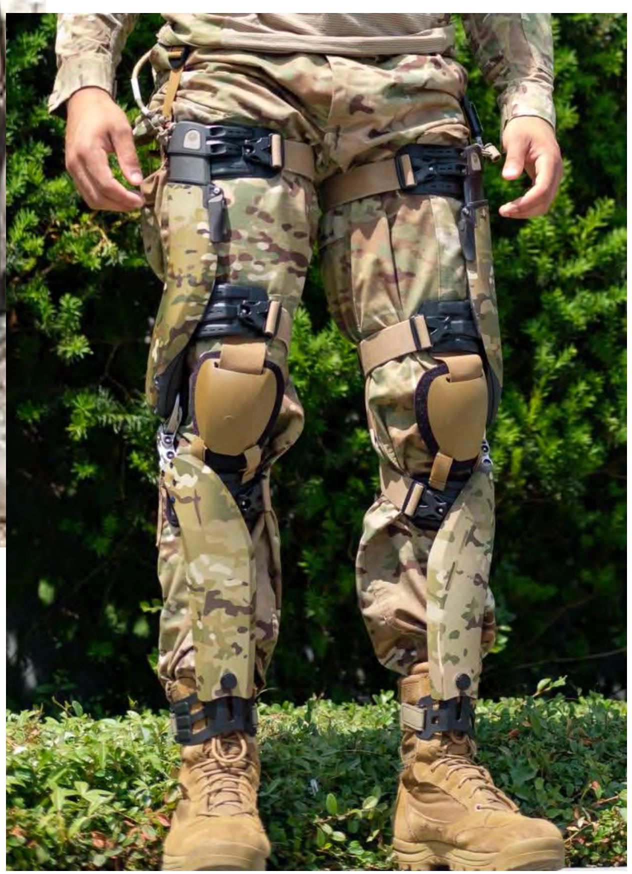



Backpack Frame Kinetic Harvester

- Energy generator based on frequency and mass
- Power: 8 – 40 W
- Weight: 10 lbs. frame
- Material: plastic
- Can be used as a static power generator
- Ruggedized frame able to handle up to 100 lbs.

Kinetic Knee Harvester

- Energy Generator based on knee movement
- Power = 9-12 W
  - Uphill ≈ 6 W
  - Downhill ≈ 30 W
- Weight: 5 lbs
- Materials: Kevlar and carbon fiber
- GPS denied navigation
- Augmentation (fatigue reduction)



Observations

- Energy requirements are rising exponentially and is becoming an unsustainable trend for the dismounted Soldier
- Current battery load is 16-20 lbs.
- Other capabilities (UAS, UGS, etc.) add additional power requirements and associated weight
- Emerging capabilities (augmentation) will add to the overall power demand

“I don’t care if I am low on everything, as long as I have power, I can call for those items that I need”

CO from a 25th ID company

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

LASERS FOR DEW BASED ON FULLY CRYSTALLINE FIBERS

Mark Dubinskii[1], Jun Zhang[1], Viktor Fromzel[1], Stuart Yin,[2,3] and Claire Luo[3]

[1]US Army Research Laboratory, Adelphi, MD,

[2]Penn State University, University Park, PA, [3]General Opto Solutions, LLC, State College, PA

22 AUG 2018

ASSL – DISRUPTIVE TECHNOLOGIES

ARL's Advanced Solid State Laser (ASSL) Team:

- Develops disruptive technologies
- Supports CFT Priorities:
  - Army Air and Missile Defense (AMD)
    - HEL Enabling/Support Technologies w/SMDC for DEW systems development
  - Future Vertical Lift (FVL)
    - Aircraft Survivability w/CERDEC

ARMY RELEVANCE

- Mission: Develop compact and reliable high power laser sources (HELs) for Counter-Rocket/ Artillery/Mortar (C-RAM) applications
- Challenge: Reduce system Size Weight and Power (SWaP) and complexity for smaller platforms
- ARL Essential Research Program (ERP) "Distributed & Cooperative Engagements in Contested Environments"
  - "HEL with Low SWAP-C" Technology Gap

Current State of the Art

High Energy Laser Mobile Test Truck (HELMTT)

- 60 kW HELMTT Master Laser with 58 individual spectrally combined ~1kW fibers
- Next short term Army goal – 100 kW class Master Laser on Stryker Combat Vehicle

KEY TECHNICAL CHALLENGES

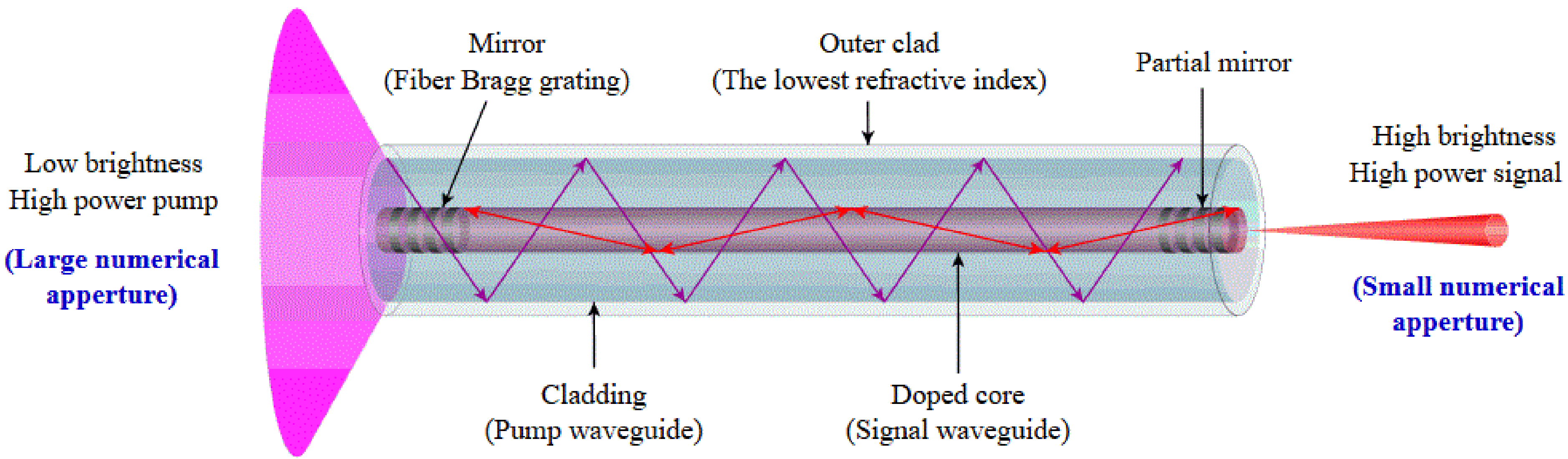
- Current System Limitations
  - Laser DEW based on current SOA in fiber lasers
  - Must combine multiple fibers to increase power
  - HELMTT Master Laser: 58 individual 1kW fibers
  - Too big for small Army platforms
- Major SWAP Reduction Needed
  - Increase power per fiber 10-50X
  - Only 2 lasers to be combined - to get 100 kW
- ARL approach – explore laser power scaling based on fully crystalline gain fibers
  - Theoretical predictions from 2010 [1,2]
  - First laser demonstrations based on fully crystalline double-clad fibers [3,4]

Smallest Army Platforms

BLUF: Laser power out of a single fiber can be scaled by a factor of 10-50X

DOUBLE CLAD FIBERS

How does the double clad fiber work:



'All-Glass' Fiber or **'Fully Crystalline' Fiber**

a.k.a. "crystalline core/crystalline cladding" (CCCC = C4) fiber

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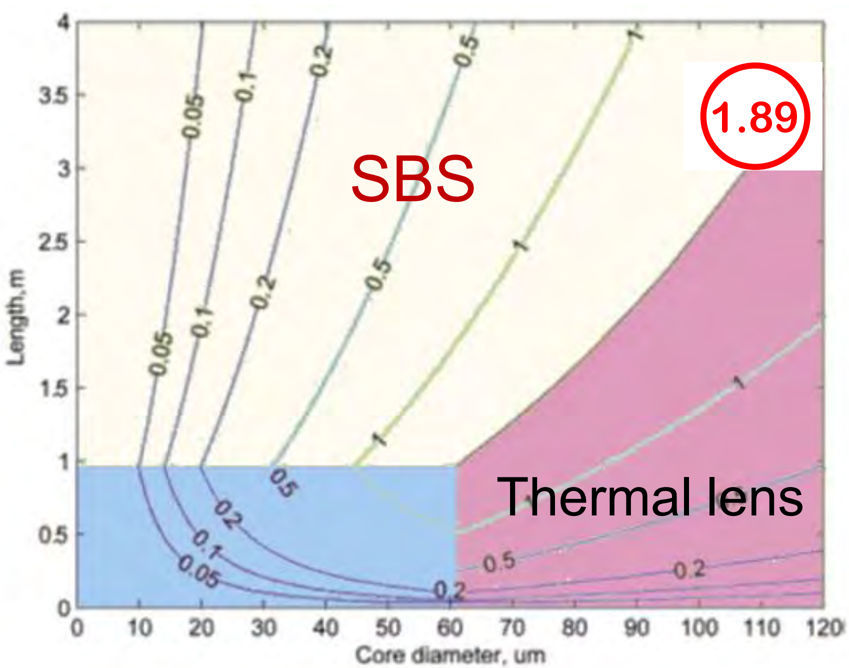
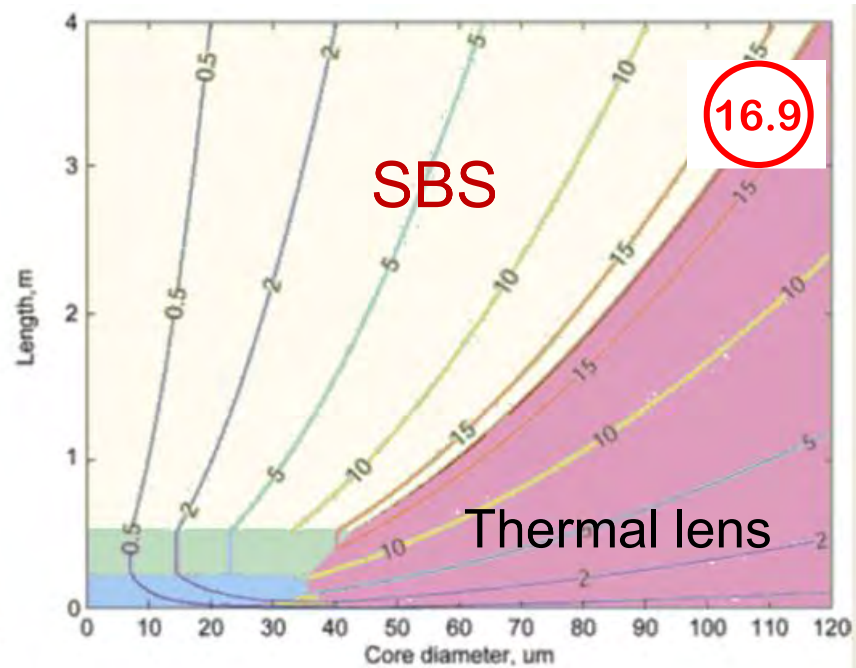
POWER SCALING POTENTIAL OF C4 FIBERS OUT OF A SINGLE FIBER APERTURE

Maximum laser power in Yb-doped C4 YAG-fiber case is (conservatively) 10X the maximum expected power in the Yb^{3+} doped silica fiber



'All-Glass' Fiber



REF(1)

'Fully Crystalline' Fiber

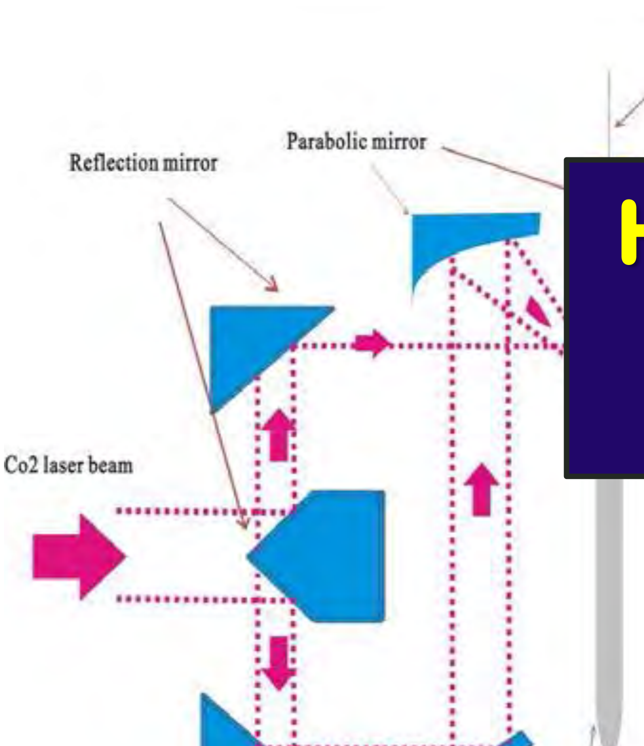
SBS – Stimulated Brillouin Scattering
YAG – Yttrium Aluminum Garnet crystal

Pump diode brightness
Damage limited

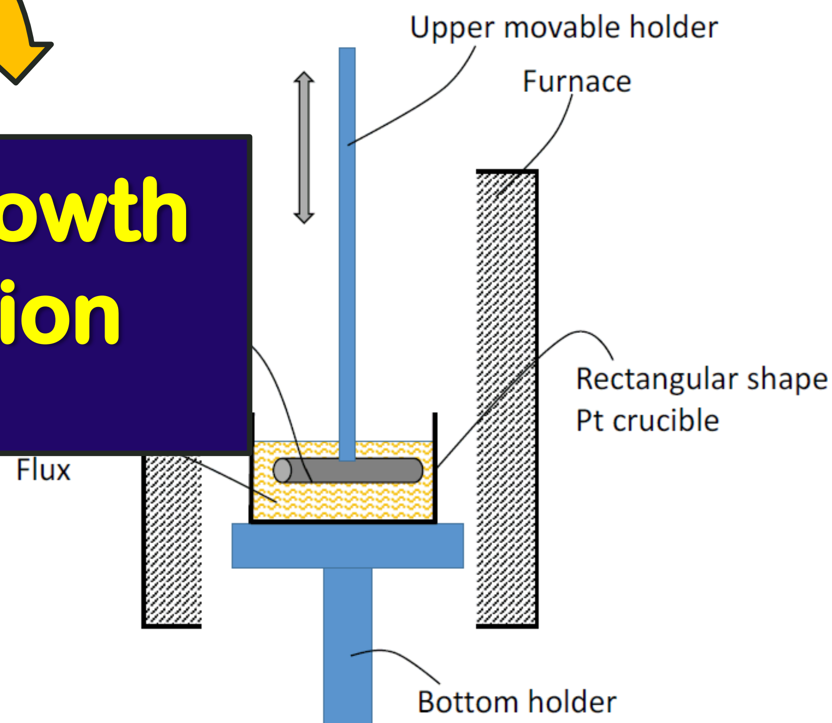
C4 FIBER VIA HYBRID GROWTH FABRICATION APPROACH (HGFA)

Laser heated pedestal growth (LHPG) for core fabrication

Liquid Phase Epitaxy (LPE) for cladding fabrication



Hybrid Growth Fabrication



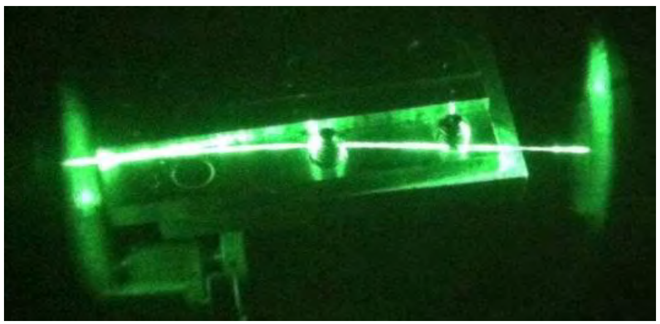
RESULT

Length-scalable and coilable C4-design low-loss laser fibers

FIRST STEPS IN FABRICATION AND TESTING

Highly efficient waveguided laser operation of RE-doped cores:

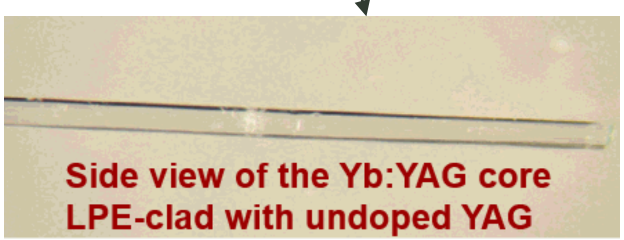
Core composition	Pump source, wavelength	Slope efficiency	Laser wavelength	Fiber dimensions	Straight or bent
Yb^{3+}(1%):YAG (Ref. [2])	Multimode laser diode module, 969 nm	58.3% - - (published) **Most recent results: 78%**	1030 nm	100 mm, dia. 100 µm	Both straight, and bent to a dia. of ~30 cm

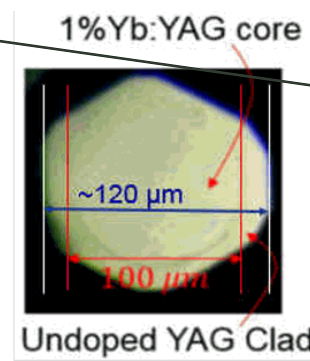


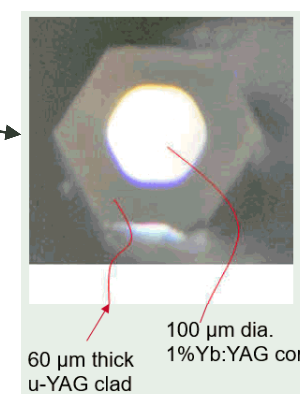
Waveguided laser operation of intentionally bent unclad Yb:YAG core. Observed with the same slope efficiency as with the straight core

LHPG-grown YAG cores are good enough for fabrication of C4 DC fibers

Fabricated double-clad C4 fibers

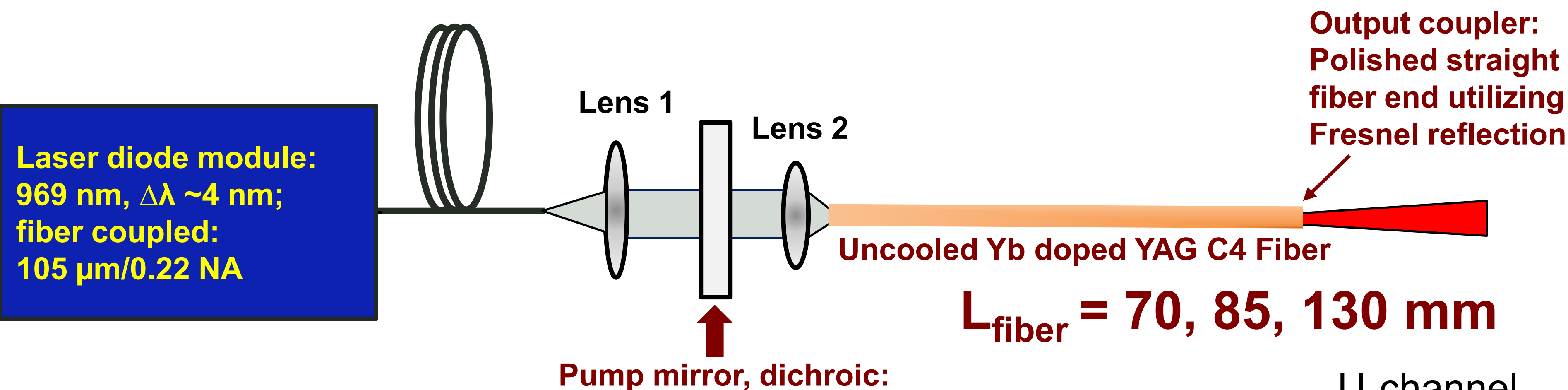


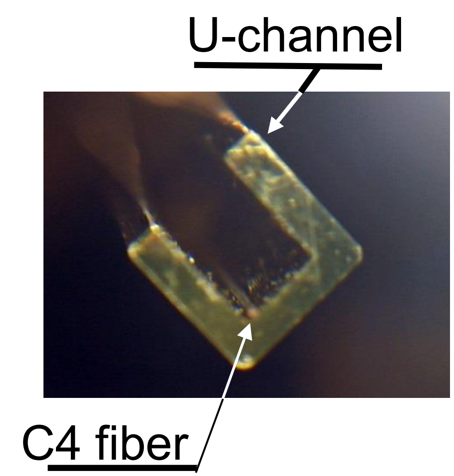




EXPERIMENTAL LASER SETUP

Co-pumped C4 fiber laser setup

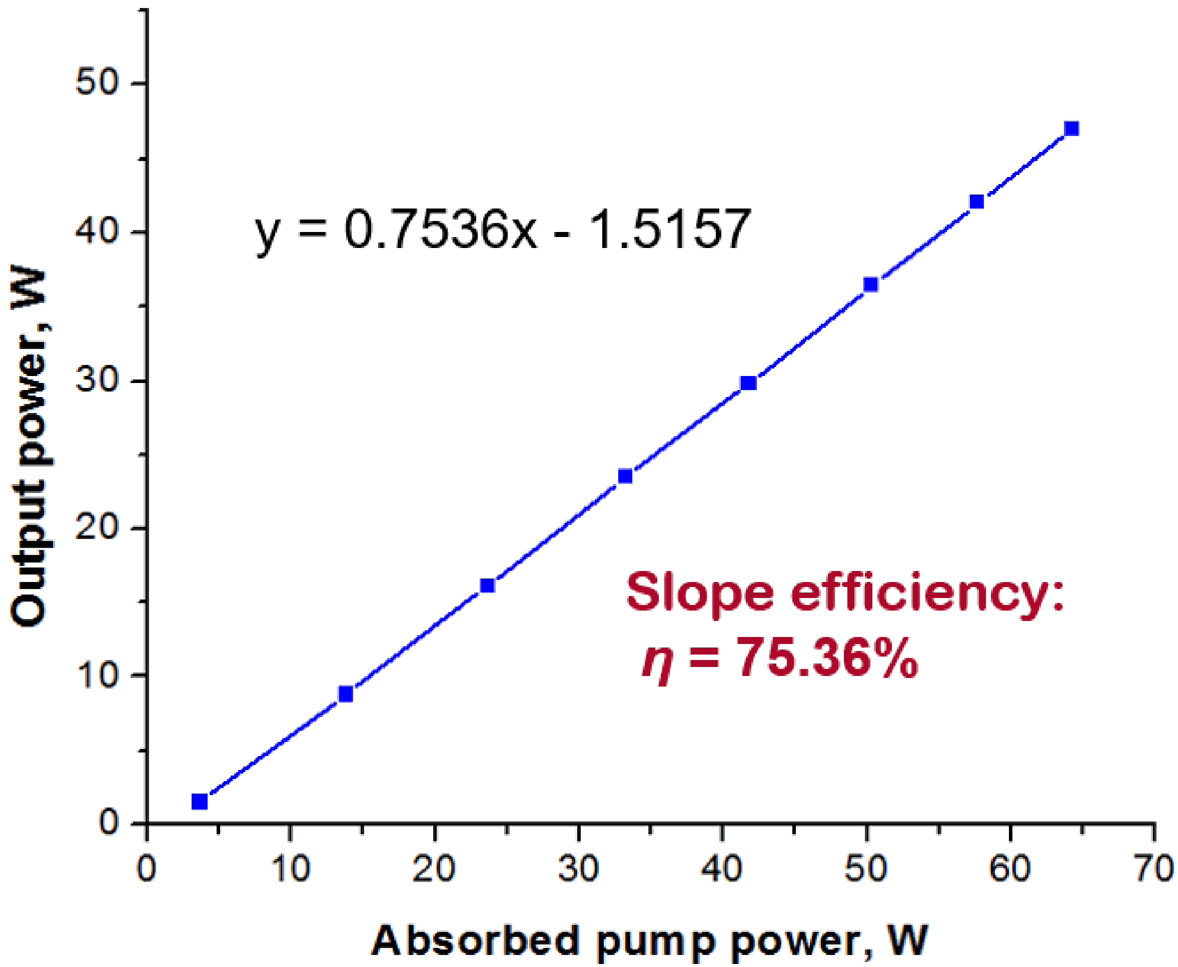




Q-CW pump regime of testing:
1 ms pump pulse duration, 1% duty cycle.

BEST LASER EFFICIENCY SO FAR

Results after pump mode and cavity optimization

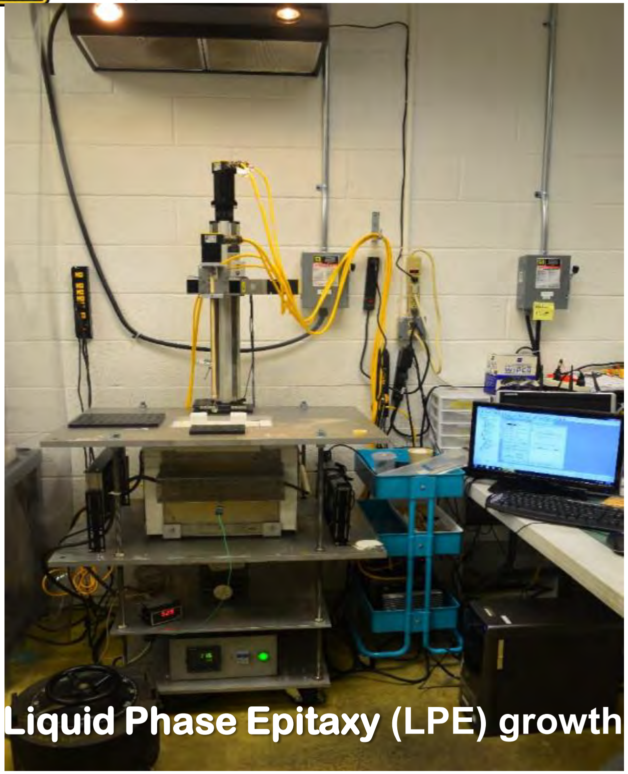


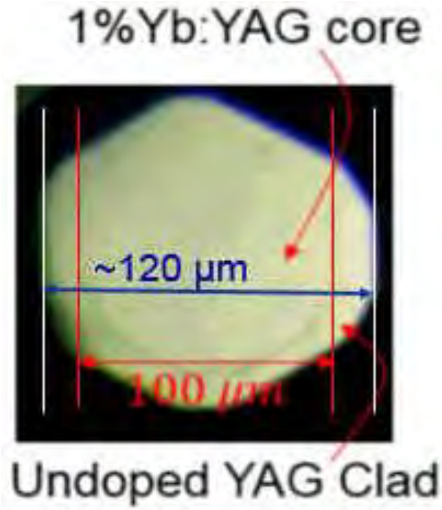
CONCLUSIONS

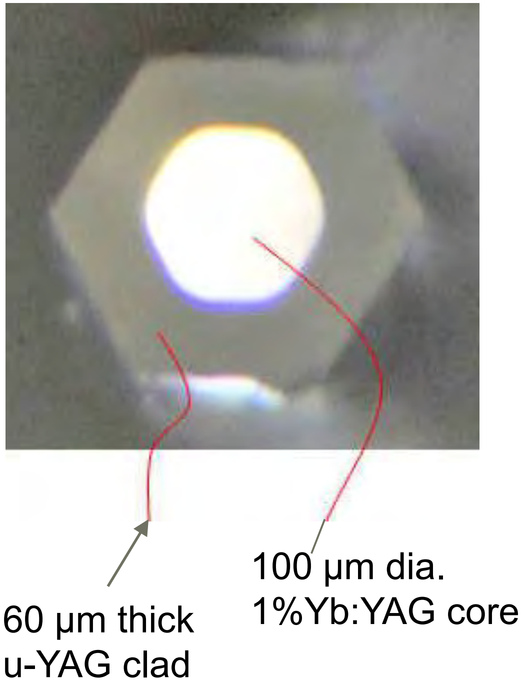
- Power scaling in crystalline-based fibers shown to be theoretically feasible
- Fabrication of the ‘crystalline core/crystalline cladding’ (C4) fibers was demonstrated using the Hybrid Growth Fabrication as a combination of LHPG and LPE
- Demonstrated ~50 W of Q-CW power from an uncooled ‘Yb:YAG core/undoped-YAG clad’ C4 fiber with ~70% optical-to-optical efficiency and over 75% slope efficiency
- Improvements in the quality of a double-clad C4 fiber will yield greater power and efficiency
- C4 fiber design upgrades for true CW operation are in progress
- This work demonstrates a viable pathway to major SWaP and complexity reduction of laser DEW systems in support of AMD

Backup slides

YB:YAG/YAG C4 FIBER – LPE CLAD







n_{YAG} (1030 nm) = 1.8153

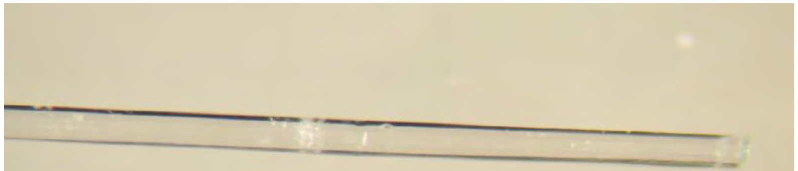
$n_{Yb(1\%):YAG}$ (1030 nm) = 1.8155

Core NA = 0.027

V number = 8.22

So this fiber core was never meant to be a singe-mode one

Growing thicker cladding is possible, but we do not currently specifically push for it



Side view of the Yb:YAG core LPE-clad with undoped YAG

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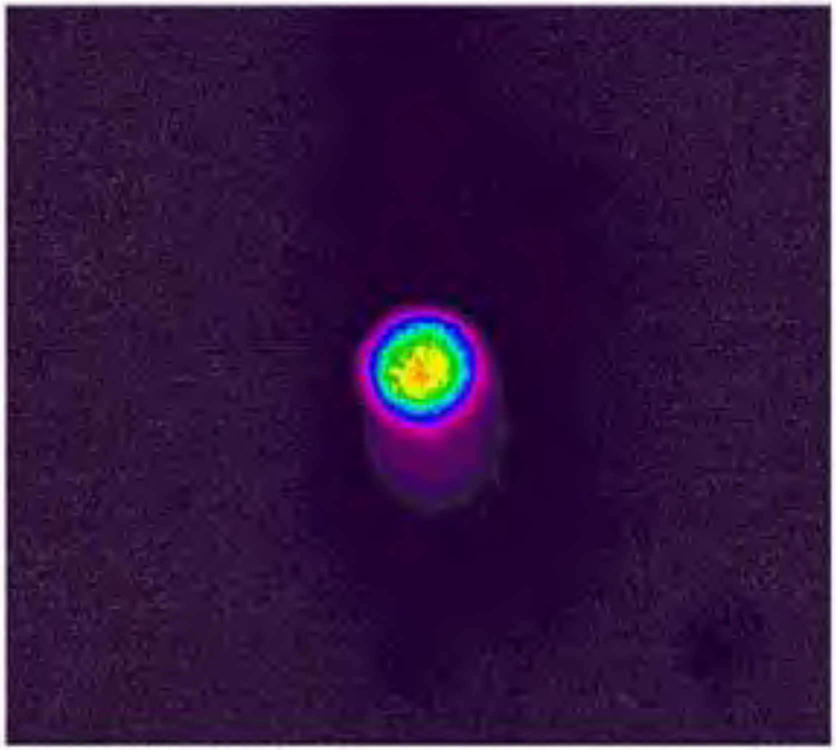
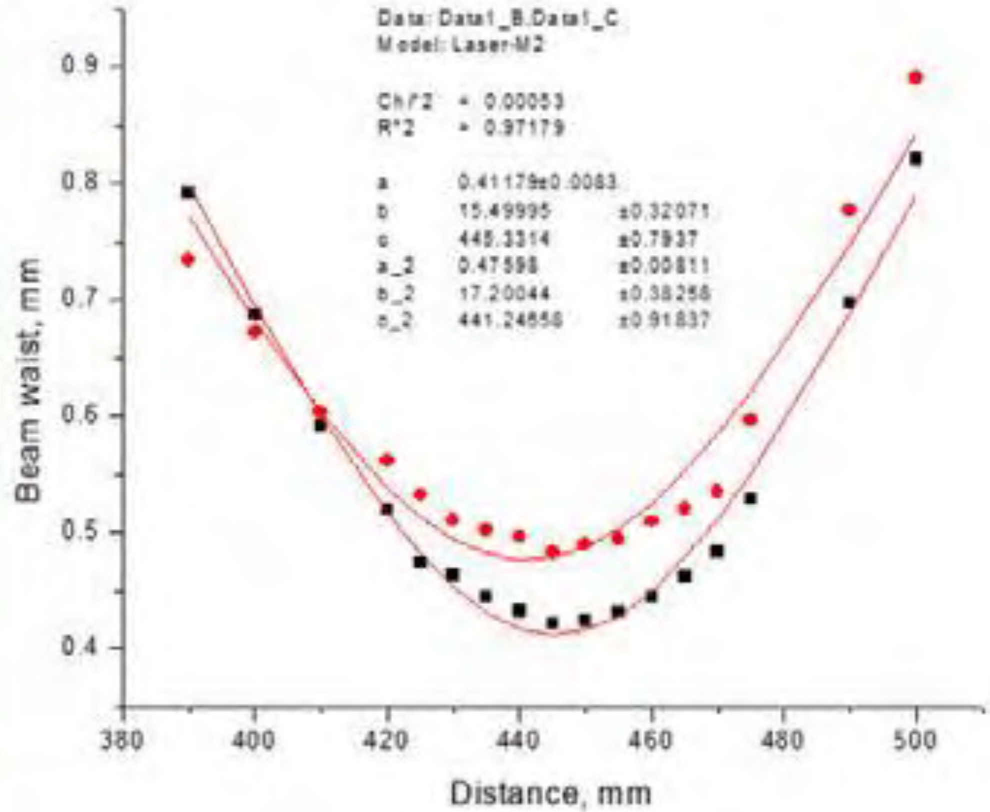
EXPERIMENTAL RESULTS - BEAM QUALITY

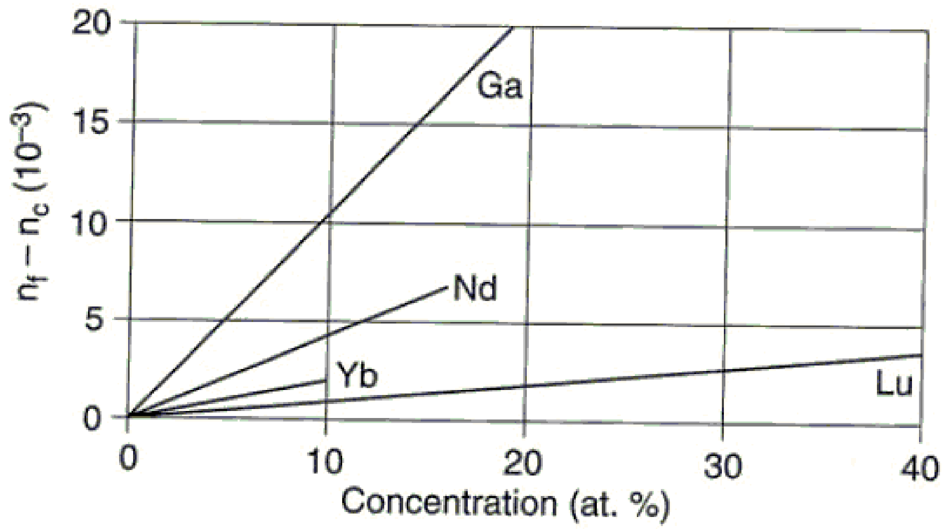


Far field laser output spatial power distribution



M^2 measurement results: M^2_x~15, M^2_y~17

HOW DO WE DESIGN THE C4 FIBER FOR A SINGLE-MODE OPERATION



M. Malinowski, J. Sarnecki, R. Piramidowicz, P. Szczepanski, and W. Wolinski, "Epitaxial Re3+:YAG planar waveguide lasers," Opto-Electronics Review 9, 67-74, 2001.

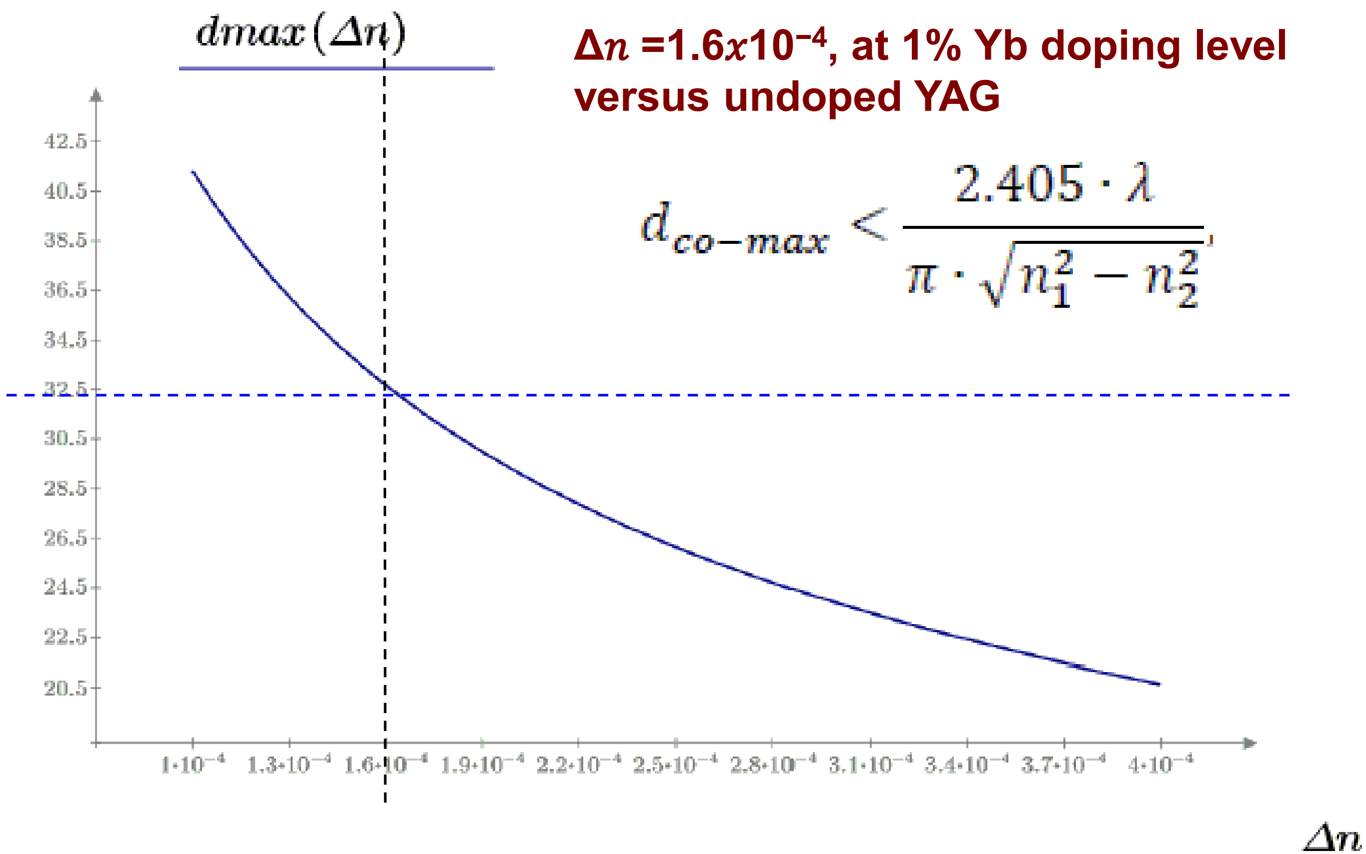
Refractive index change rate in commonly used RE-doped YAG crystals.

RE dopant	Lu	Yb	Tm	Er	Ho	Nd
$\Delta n(\times 10^{-4})/1\%$	0.96	1.60	2.08	2.10	2.44	4.74

X.Mu, H.Meissner, H-C.Lee, M.Dubinskii, "True Crystalline Fibers: Double-Clad LMA Design Concept of Tm:YAG-Core Fiber and Mode Simulation", Proc. of SPIE Vol. 8237, 82373M (2012)

CAN WE TURN THIS LASER INTO A SINGLE TRANSVERSE MODE DEVICE?

Calculated maximum core diameter as a function refractive index difference between core and cladding



$\Delta n = 1.6x10^{-4}$, at 1% Yb doping level versus undoped YAG

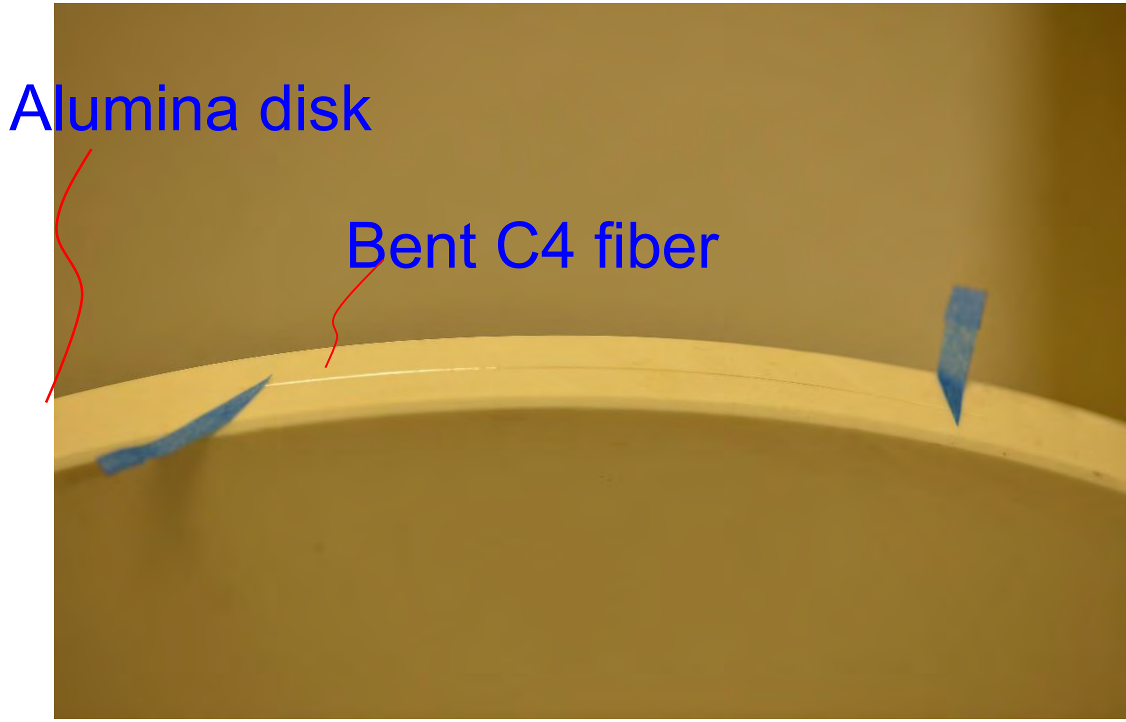
$$d_{co-max} < \frac{2.405 \cdot \lambda}{\pi \cdot \sqrt{n_1^2 - n_2^2}},$$

All we need to do (for Yb^{3+} 1% doping in YAG vs undoped YAG) is to go to a core diameter of ~30 μm, which is shown to be very feasible for LHPG-grown cores

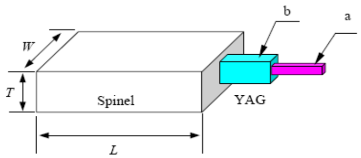
C4 FIBER - BENDABILITY

We demonstrated the bending (or coiling) capability of our C4 fiber, enabling future operation when the length extents to over 0.5 m, or so

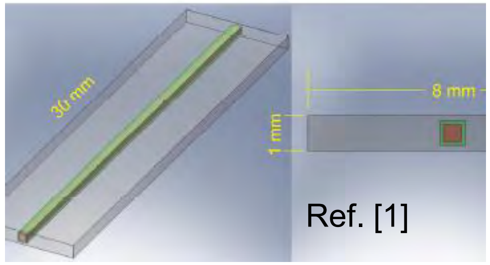
Shown to the right is the C4 fiber bent on an alumina disk with a diameter around 30 cm

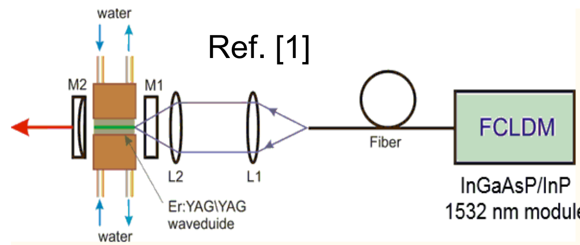


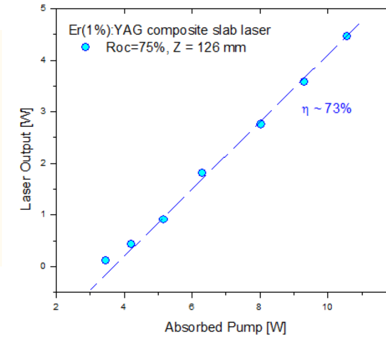
SMALL CRYSTALLINE WAVEGUIDING STRUCTURES: OUR EARLY ANALOG OF CCCC (C4) FIBER



Fully crystalline double-clad fiber design based on diffusion bonding

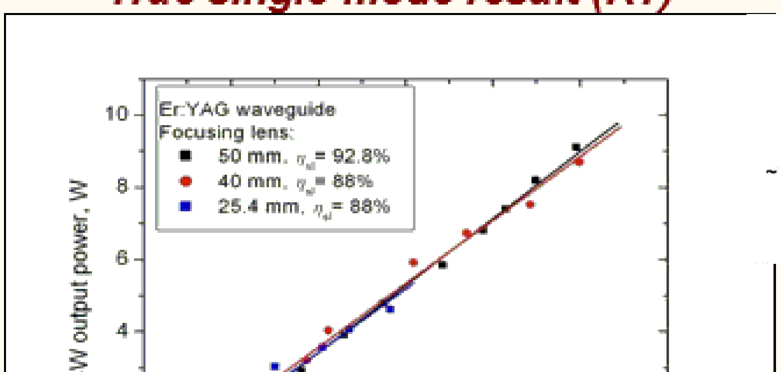


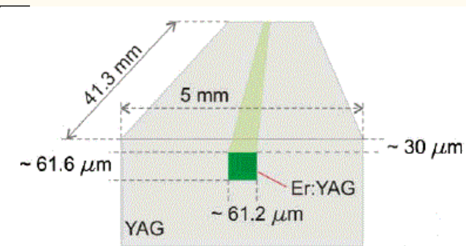




[1] N. Ter-Gabrielyan, V. Fromzel, X. Mu, H. Meissner, and M. Dubinskii, "High efficiency, resonantly diode pumped, double-clad, Er:YAG-core, waveguide laser," Opt. Express 20 (23), 25554-25561 (2012) .

True single-mode result (RT)

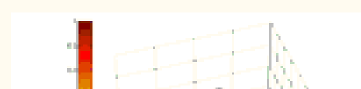




Composite "Er:YAG/YAG" buried channel waveguide

(60 x 60) µm SC core

Ref. [2]



First experiments with fully-crystalline fiber-like double-clad structures in bulk crystalline materials provided a proof-of concept, but, based on fabrication technique, are not amenable either to major length scaling, or fiber coiling

Preliminary Characterization of Head-Supported Mass Exposure in a Simulated Dismounted Operating Environment

Bethany L. Shivers, Ph.D.[1], Adrienne M. Madison, Ph.D.[1,2], Patrick N. Estep[1,2], Frederick Brozoski[1], M. Reid Holderfield[1,3], Valeta Carol Chancey, Ph.D.[1]

[1]U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, AL
[2]Laulima Government Solutions, LLC, Orlando, FL
[3]Oak Ridge Institute for Science and Education (ORISE), Oak Ridge, TN

Disclaimer

The opinions, interpretations, conclusions, and recommendations are those of the presenter and are not necessarily endorsed by the U.S. Army and/or the U.S. Department of Defense. Citation of trade names in this presentation does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Acknowledgements

- Equipment used in this study was provided by PEO Soldier.
- This work was supported by U.S. Army Medical Research and Materiel Command (USAMRMC).
- This research was supported in part by an appointment to the Postgraduate Research Participation Program at the U.S. Army Aeromedical Research Laboratory administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and USAMRC.

Head-Supported Mass

Head-Supported Mass (HSM) = helmets and helmet-mounted systems

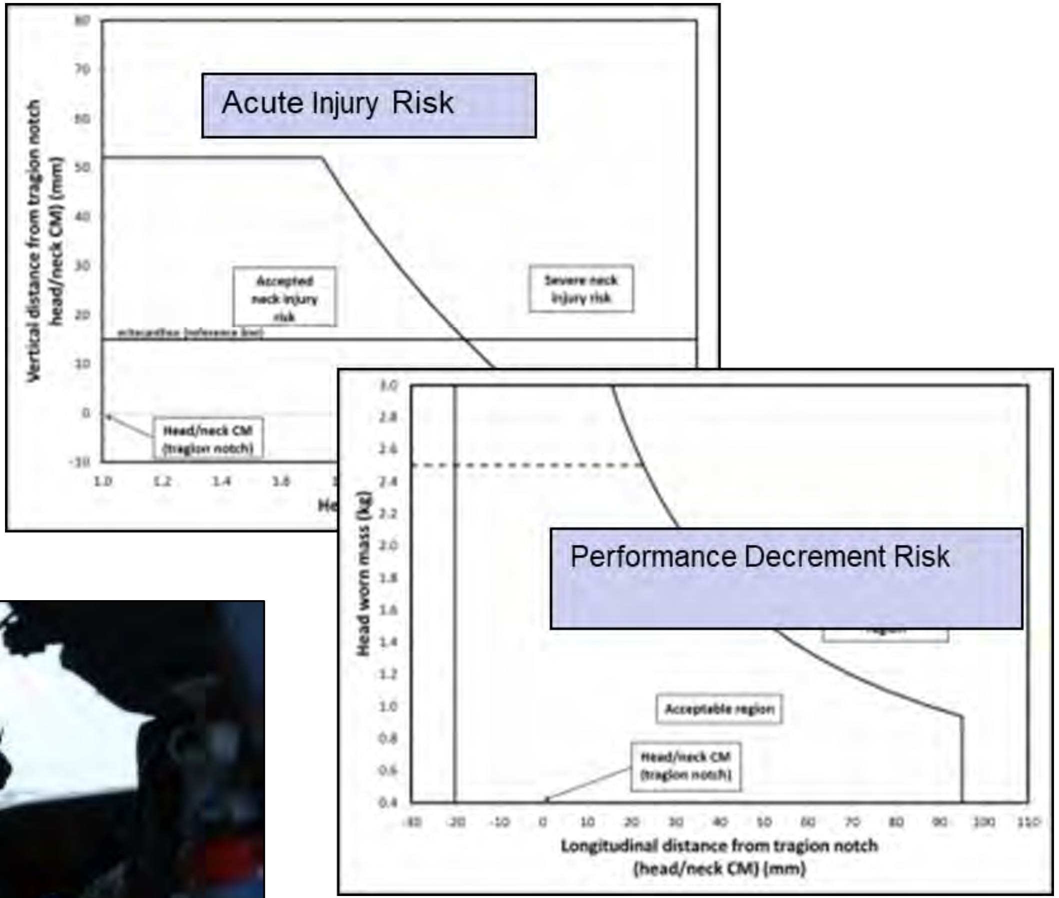
- Military helmets provide Soldier protection and enable use of advanced electronic systems, e.g., night vision goggles or communications systems
- Head-supported mass has been linked with decreased performance and increased injury risk
  - 90,456 (12%) Army Ground Soldiers in Infantry, Armor, and Amphibious MOSs sought treatment for spine-related conditions between 2006-2015 (Defense Medical Epidemiology Database)
  - 70% of those Soldiers were under the age of 30 at the time of the treatment
- Existing HSM criteria do not include guidance for rapid technology advancements
- **No** HSM criteria exist for **mounted** or **dismounted** Ground Soldiers




We must know the performance effects and injury risk of HSM to establish helmet and helmet-mounted device performance specifications for emerging technology.

Existing HSM Guidance

- Existing HSM guidelines developed by USAARL around aviation-type exposures (McEntire, 1998)
  - Acute Injury Risk
  - Performance Decrement



Operational Need

- Different operating environments have different exposures and movement requirements
- PEO Soldier needs HSM guidelines for dismounted Soldiers

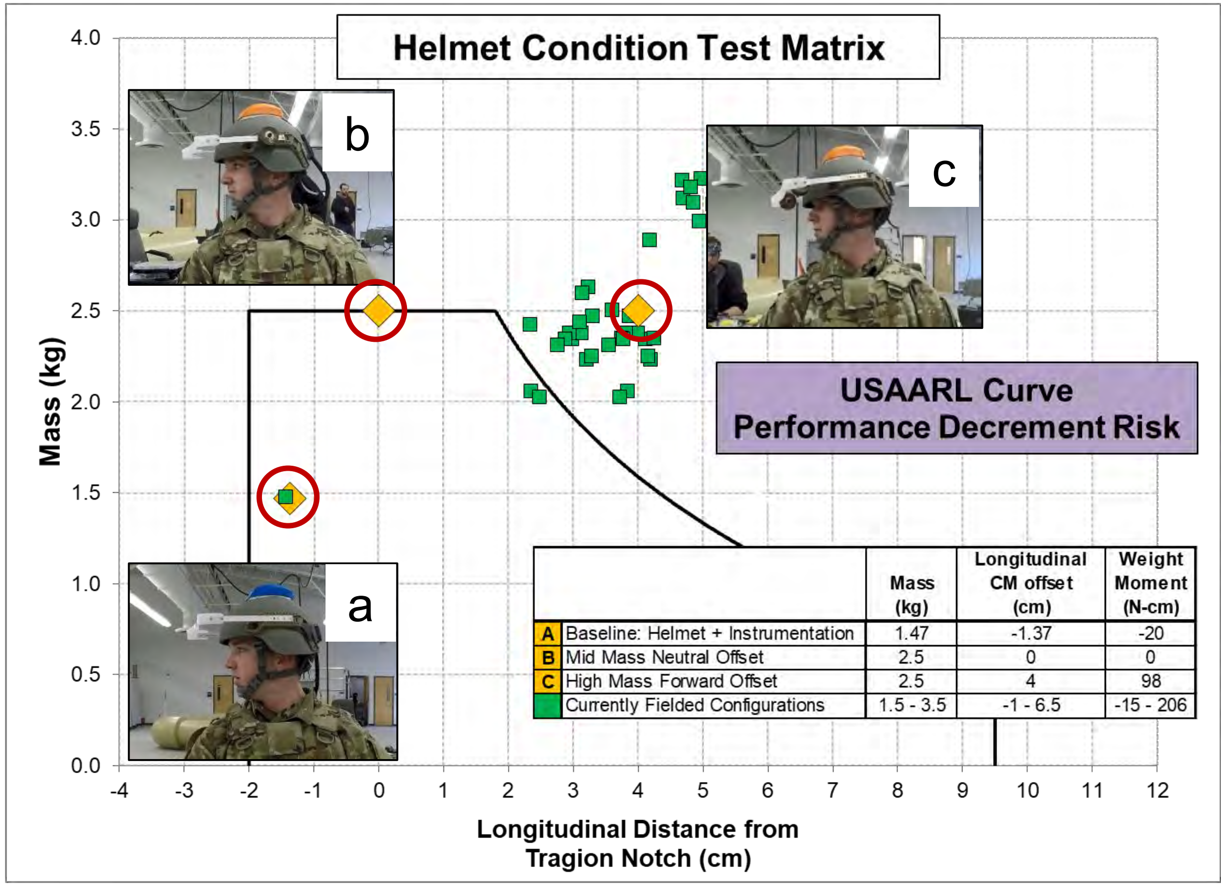
Pictures from Defense Visual Information Distribution System (DVIDS)

<u>#1 Research Gap:</u> Characterize the operating environment relative to exposures received during individual maneuvers
(HSM Expert Panel Working Group, 2016)

Methods: Overview

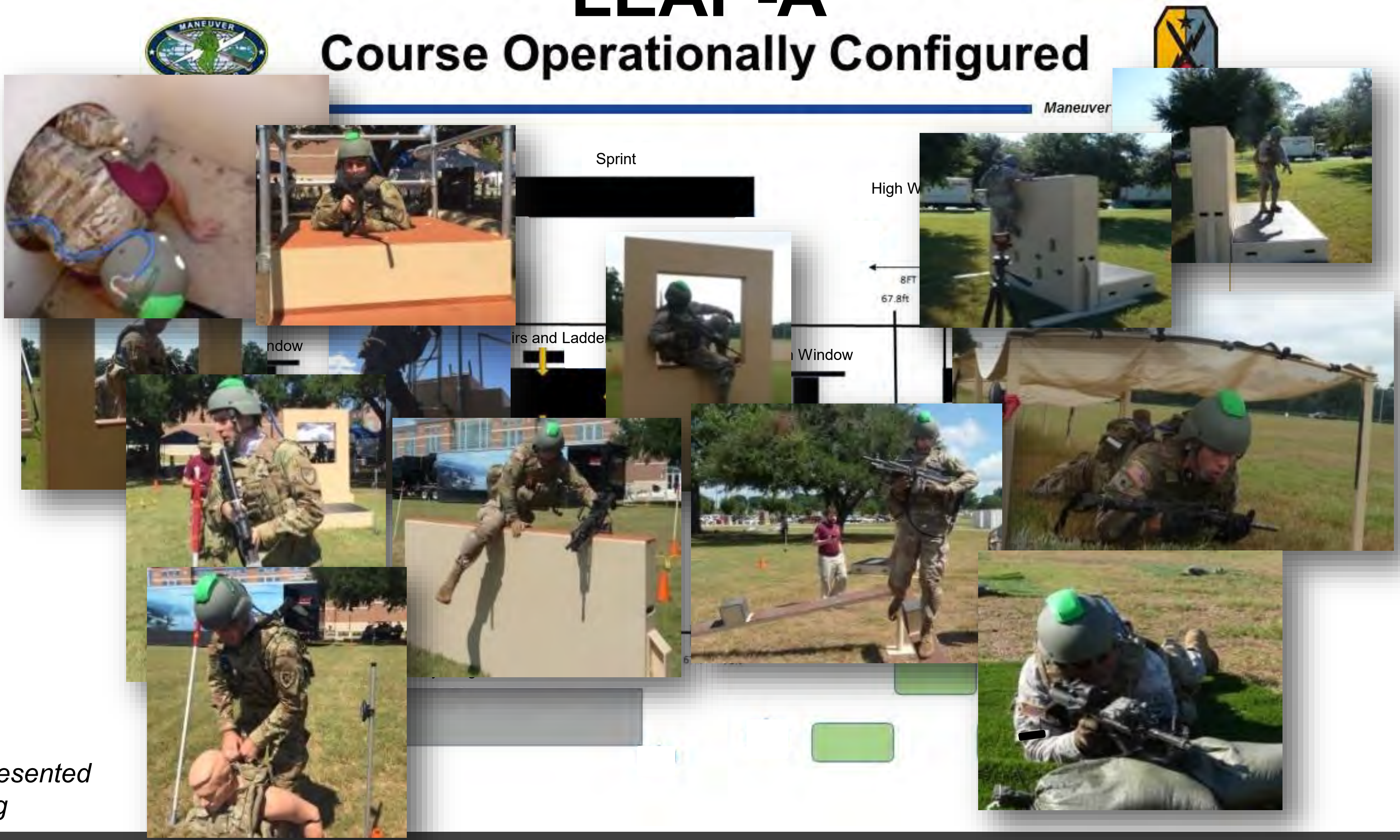
- USAMRMC IRB-approved volunteer research protocol
- Load Effects Assessment Program-Army (LEAP-A), Fort Benning, GA
- TRADOC non-medical holdovers
- Body armor (IOTV3 in basic rifleman configuration)
- Simulated HSM conditions: Varied mass and center of mass offset*
  - a) Baseline ACH (1.5 kg, -1.4 cm rearward offset)
  - b) Mid-mass/neutral offset (2.5 kg, neutral offset)
  - c) Mid-mass/forward offset (2.5 kg, 4 cm forward offset)

  *Center of mass offset = longitudinal distance from tragion notch
- Multiple metrics from four variable groups:
  - – Kinematic: Helmet-mounted instrumentation package (acceleration, angular rotation, position)
  - – Performance: Marksmanship task
  - – Physiologic/Biomechanical: Muscle activation, neck strength, range of motion
  - – Subjective: Pain, fatigue, exertion, user acceptance



All subjects provided written consent for use of identifiable pictures and video.

LEAP-A



Obstacles not presented in order of testing

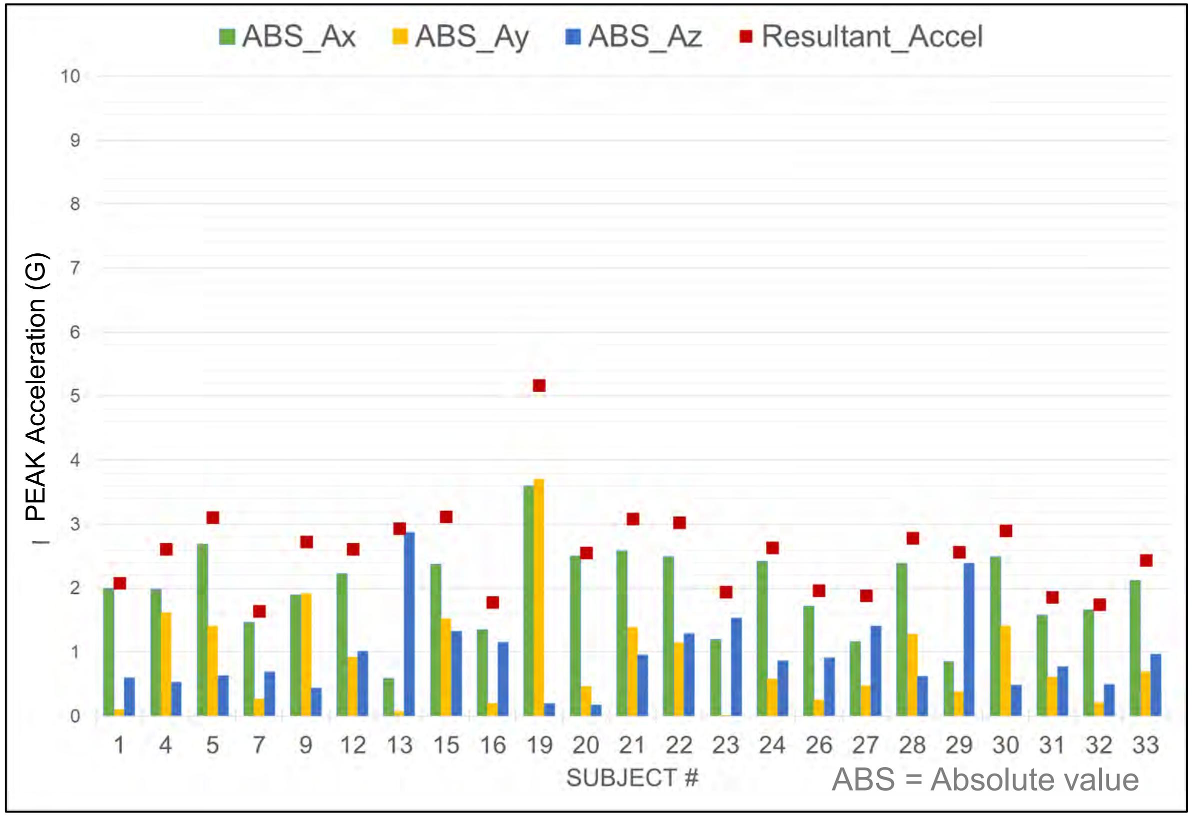
Methods: Data Down-select

- Acceleration
  - X, Y, Z, resultant
  - Captured at 2500 Hz
  - Time synced with video
- Only 2 of the 12 main LEAP-A obstacles
  - Dive to prone
  - High Wall
- Single HSM configuration
  - 2.5 kg with 4 cm forward offset
  - Representative of common dismounted Soldier configuration used for night operations
- Data reported for 23 subjects
  - 33 volunteers enrolled
    - 31 males
    - 2 females
  - 6 subjects withdrew before study completion
  - 4 subjects excluded for bad data

All subjects provided written consent for use of identifiable pictures and video.

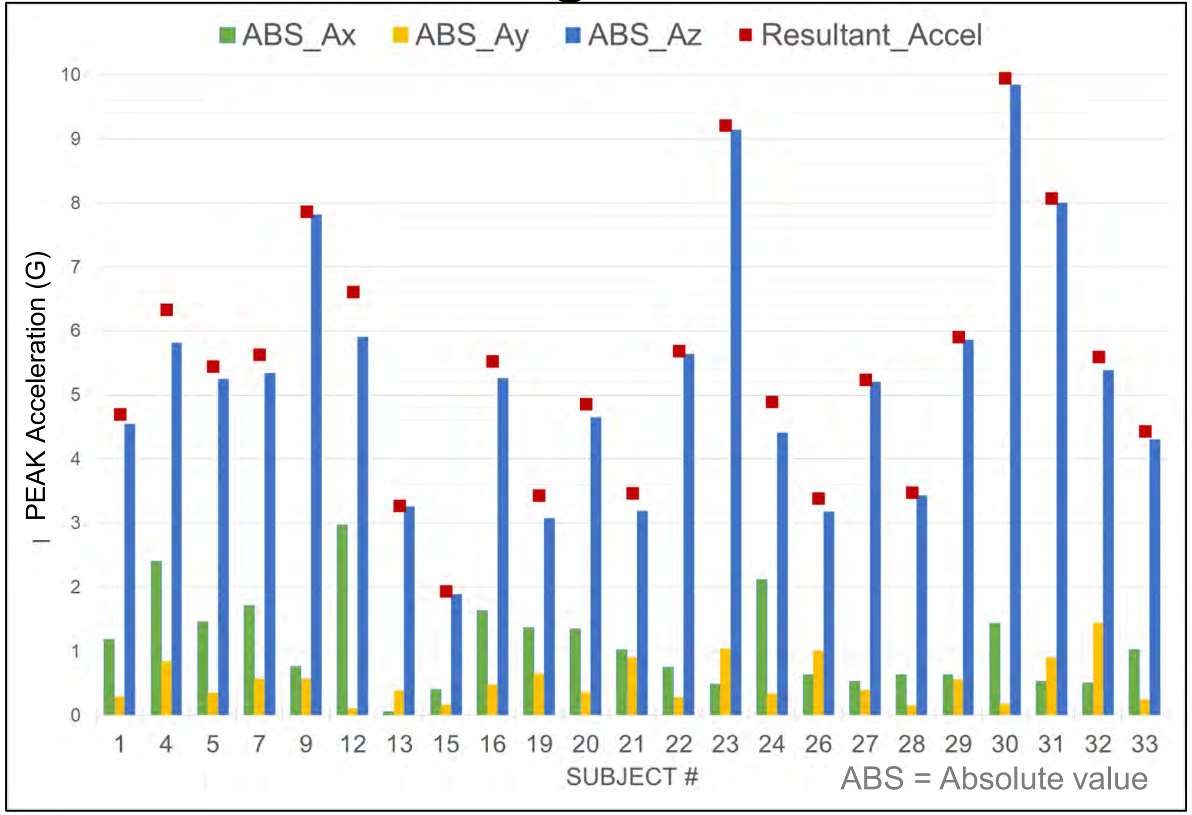
Head Resultant Acceleration Dominant Axes

Dive to Prone



- Peak acceleration summary:
  - X axis – 0.6 to 3.6G; average = 2.0G
  - Y axis – 0.02 to 3.7G; average = 0.9G
  - Z axis – 0.2 to 2.9G; average = 1.0G
  - Resultant – 1.6 to 5.2G; average = 2.6G

High Wall

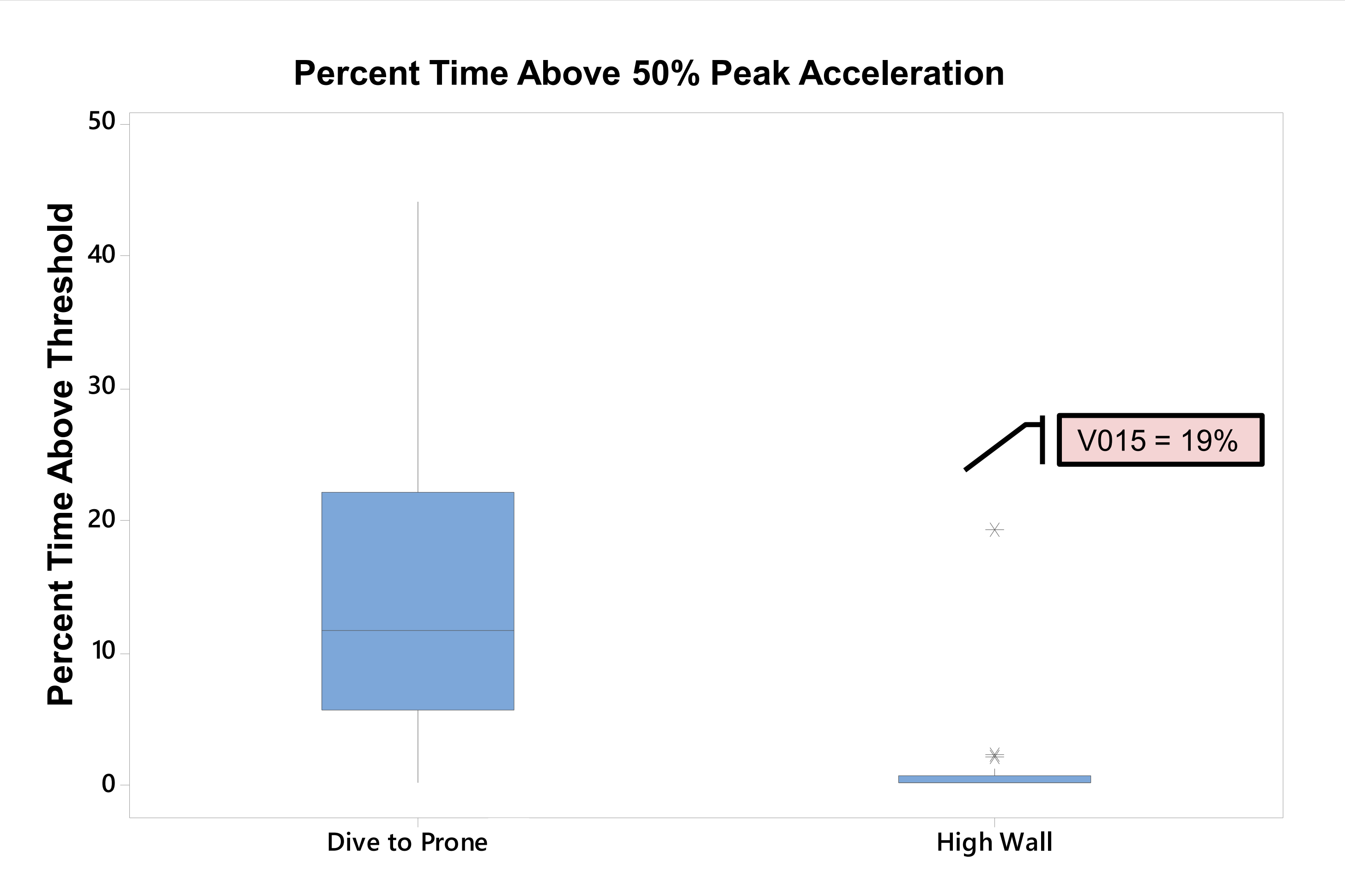


- Peak acceleration summary:
  - X axis – 0.1 to 3.0G; average = 1.1G
  - Y axis – 0.1 to 0.9G; average = 0.5G
  - Z axis – 1.9 to 9.8G; average = 5.2G
  - Resultant – 1.9 to 9.9G; average = 5.4G

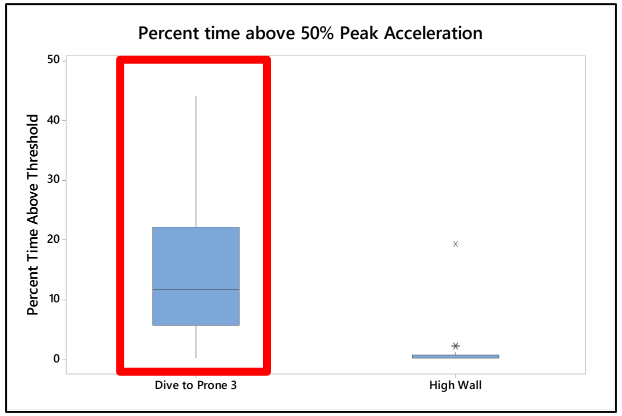
Duration Above 50% Max Head Resultant Acceleration

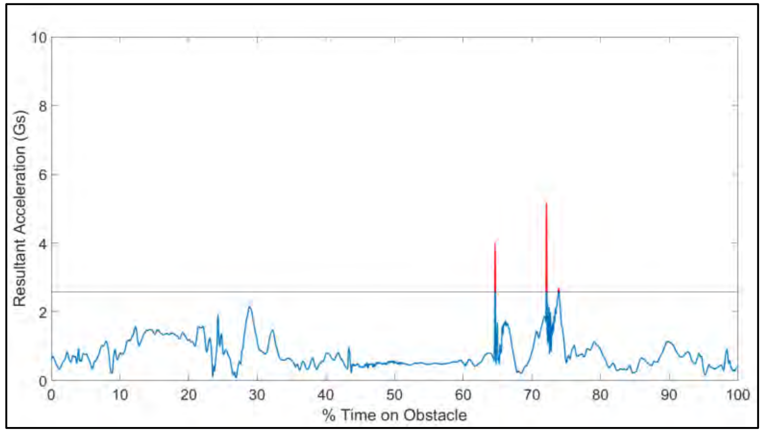
- Significant difference between obstacles for average duration of head resultant acceleration (Ar)
  - Dive to prone
    - 14% of total obstacle time
  - High wall
    - 1.4% of total obstacle time with
    - **Drops to 0.5% when outlier (V015) removed**

Technique matters



Duration Above 50% Max Head Resultant Acceleration: Dive to Prone



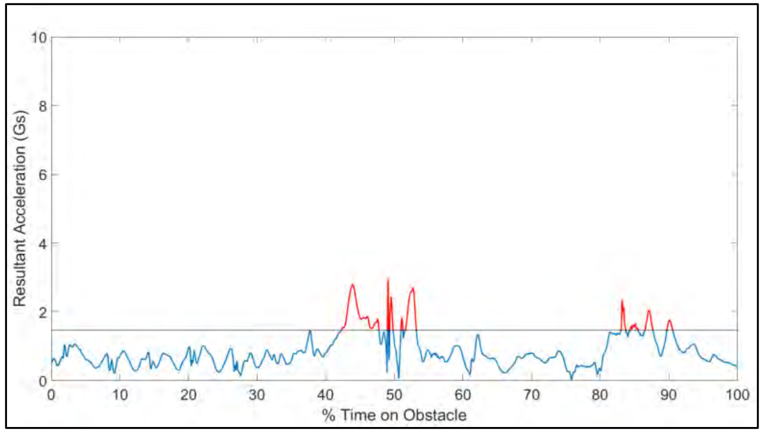


Subject 019

- Max Head Ar – 5.2G
- Duration above 50% Max Head Ar – 0.3%
- Time on Obstacle – 8.19 sec

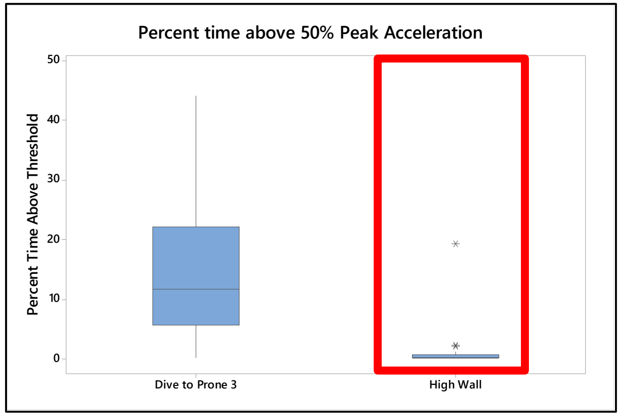
Subject 013

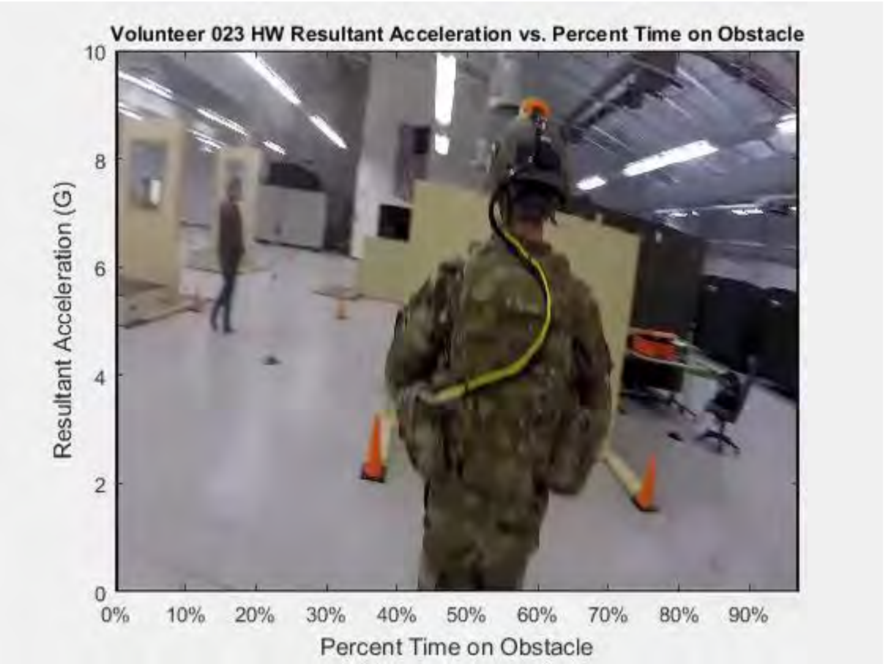
- Max Head Ar – 2.9G
- Duration above 50% Max Head Ar – 11.8%
- Time on obstacle – 6.44 sec

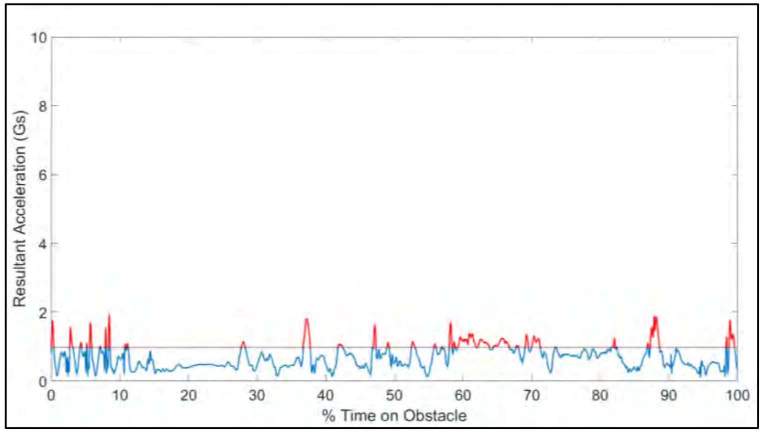


All subjects provided written consent for use of identifiable pictures and video.

Duration Above 50% Max Head Resultant Acceleration: High Wall





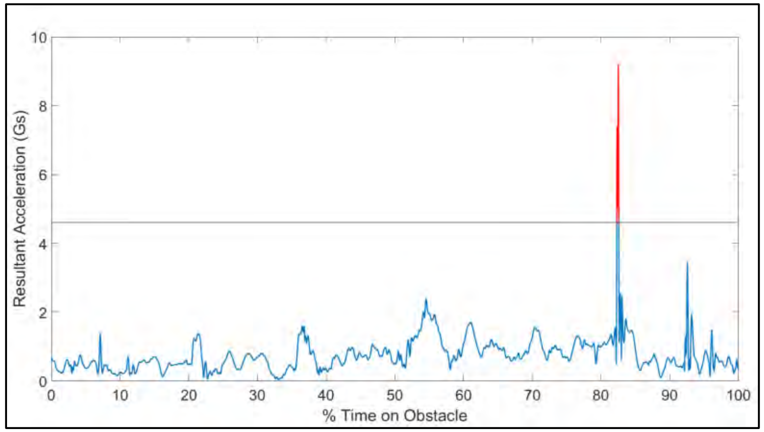


<u>Subject 015</u>

- Max Head Ar – 1.9 G
- Duration above 50% Max Head Ar – 19.2%
- Time on obstacle – 14.03 sec

<u>Subject V023</u>

- Max Head Ar – 9.2G
- Duration above 50% Max Head Ar – 0.28%
- Time on obstacle – 10.87 sec



All subjects provided written consent for use of identifiable pictures and video.

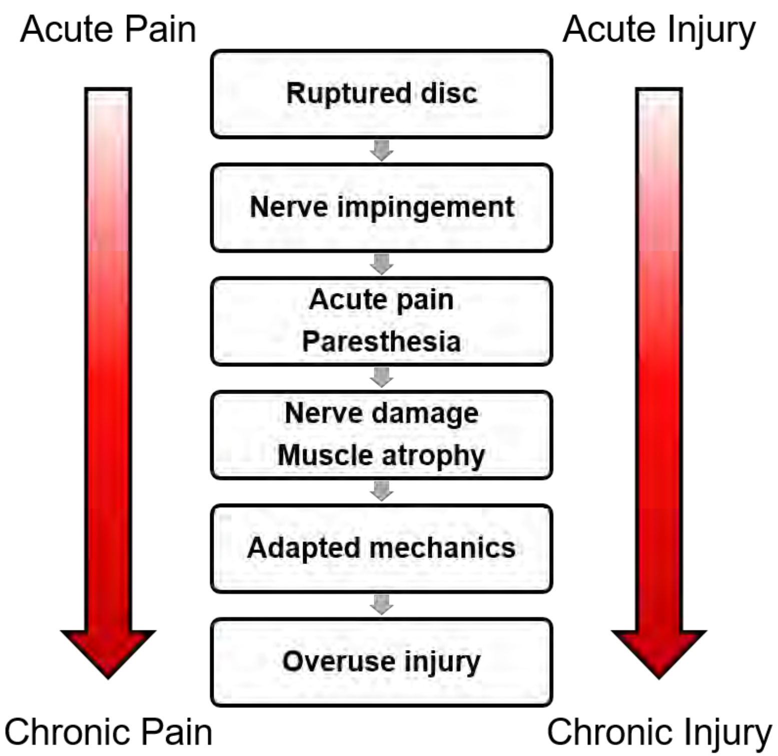
Discussion

- Unique study to characterize head acceleration in a simulated dismounted operating environment
  - First use of the LEAP-A course for research instead of test and evaluation
  - First effort to characterize the dismounted Soldier operating environment
- Resultant acceleration was low compared to previously studied environments (aviation or automotive crash), but frequency of exposure is greater.
  - Peaks were 3.5 times less than aviation crash, but higher than expected
  - Magnitude and duration varied greatly within obstacle and individual
- Study Limitations
  - Population experience – TRADOC Soldiers with limited experience performing individual movement techniques
  - Usable data on 23/33 subjects – volunteer dropout and instrumentation issues
  - Only analyzed 2 of the 12 obstacles – data analysis for remaining obstacles is underway

Conclusions

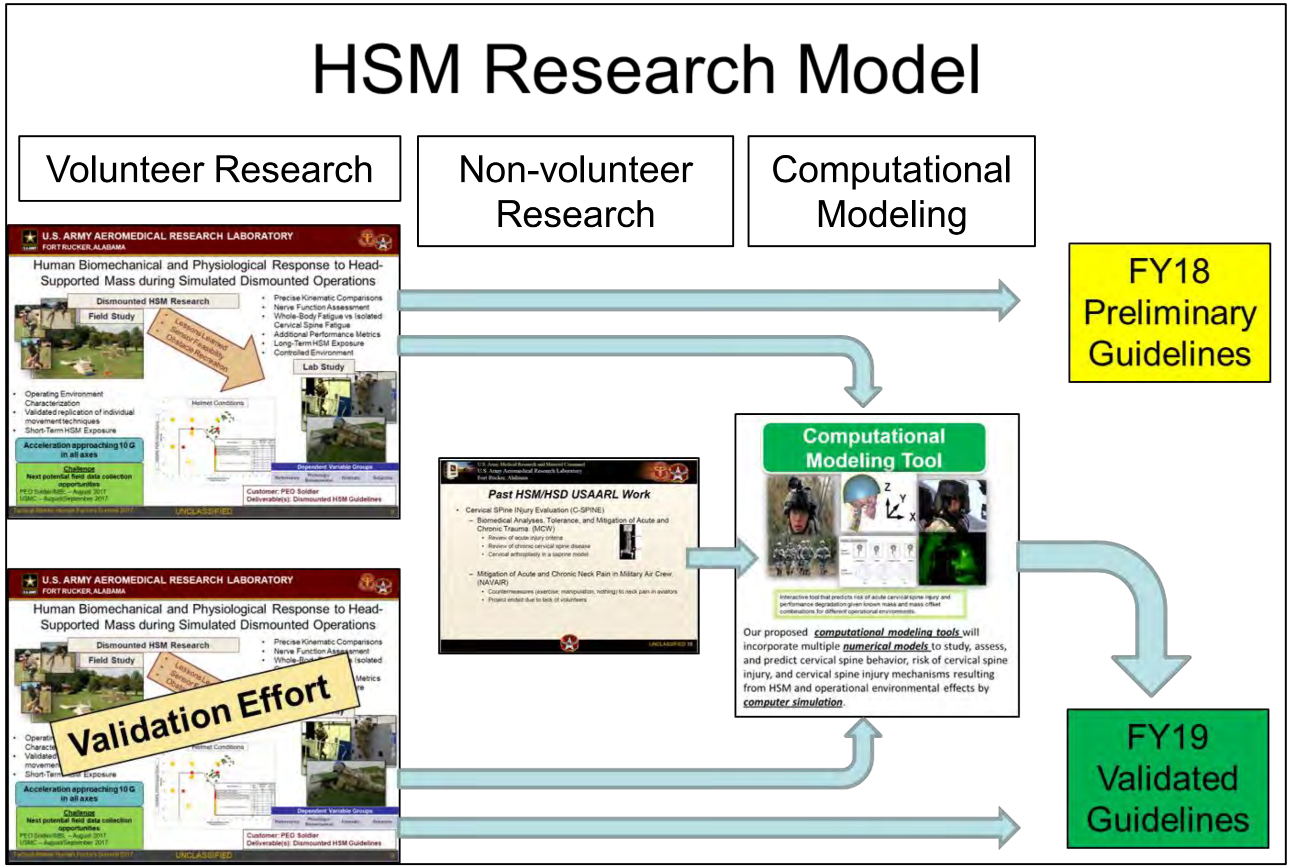
- High acceleration with short duration is an identified mechanism for acute injury. (Eiband, 1971; Gadd, 1971; and Yoganandan, 2014)
- Low to moderate acceleration with longer duration and/or greater frequency may contribute more to muscle fatigue and performance decrement.
- Designation of high, low, and moderate acceleration ranges is arbitrary and operating environment-dependent.
  - Aviation acceleration events (35 G crash) may result in AIS 3+ injuries:
    - Long-term loss of capability
    - Potentially career ending
  - Ground Soldier acceleration events (10 G landing off of a high wall) may result in AIS 2 injuries:
    - Short-term loss of capability
    - Unlikely to be career ending
- Repeated exposures to both types of ground Soldier acceleration patterns characterized may compound the effects and lead to increased risk of:
  - Acute musculoskeletal injury: sprains or strains (muscles, ligaments, tendons)
  - Performance decrement: muscle fatigue and/or muscle pain/soreness
  - Chronic injury: intervertebral disc degeneration, vertebral stress fracture

Neck pain and injury



Future Work

- Complete characterization of simulated operating environment
  - Remaining LEAP-A obstacles
  - Remaining metrics – kinematic, performance, physiologic/biomechanical, subjective
- Development of Dismounted HSM Guidelines
  - Mass/center of mass offset
  - Mass moment
  - Duration of wear
  - Operating environment or task specific



Questions?

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makerminded
Powered by
lift

What is MakerMinded?

Through a web-based competition and campaign platform, MakerMinded is connecting students to *the* leading-edge manufacturing and STEM learning experiences and opening their minds to careers in manufacturing.

1. **Activating Schools:** students sign-up at no cost and gain access to a curated portfolio of national and local STEM and manufacturing learning experiences.
2. **Inspiring Students:** students select activities to complete throughout the school year—inside or outside of the classroom. Activities include a range of career awareness experiences, formal educational resources and project or competition-based learning programs.
3. **Showcasing Students and Schools:** students submit updates for the activities they complete and their progress is documented and showcased in real-time through social media channels.
4. **Celebrating Student Success:** schools receive points for the activities their students complete, competing against other schools. Points and activities are tracked in real-time and success is celebrated at year-end awards event.

Sample Activities from Digital Portfolio

Barnes & Noble Mini Maker Faire (November 5 & 6)
MIDDLE SCHOOL, HIGH SCHOOL, SOLO

Learning Blade
MIDDLE SCHOOL, CLASSROOM

SOLO

(Solo) LIFT Simulation
MIDDLE SCHOOL, HIGH SCHOOL, SOLO

MFG DAY

Manufacturing Day
MIDDLE SCHOOL, HIGH SCHOOL, CLASSROOM

Destination Imagination Tennessee
MIDDLE SCHOOL, HIGH SCHOOL, TEAM

FIRST Robotics Competition
HIGH SCHOOL, TEAM

Science Olympiad
MIDDLE SCHOOL, HIGH SCHOOL, TEAM

SkillsUSA
Champions at Work

SkillsUSA
MIDDLE SCHOOL, HIGH SCHOOL, TEAM

VEHICLE ASSEMBLY PLANT
NISSAN
EST. SMYRNA 1983

Nissan Factory Tour (Smyrna, TN)
MIDDLE SCHOOL, HIGH SCHOOL, SCHOOLWIDE

Trash Sliders
MIDDLE SCHOOL, HIGH SCHOOL, CLASSROOM

The Future City Competition
MIDDLE SCHOOL, TEAM

FIRST LEGO League
MIDDLE SCHOOL, TEAM

MATHCOUNTS Video Challenge
MIDDLE SCHOOL, TEAM

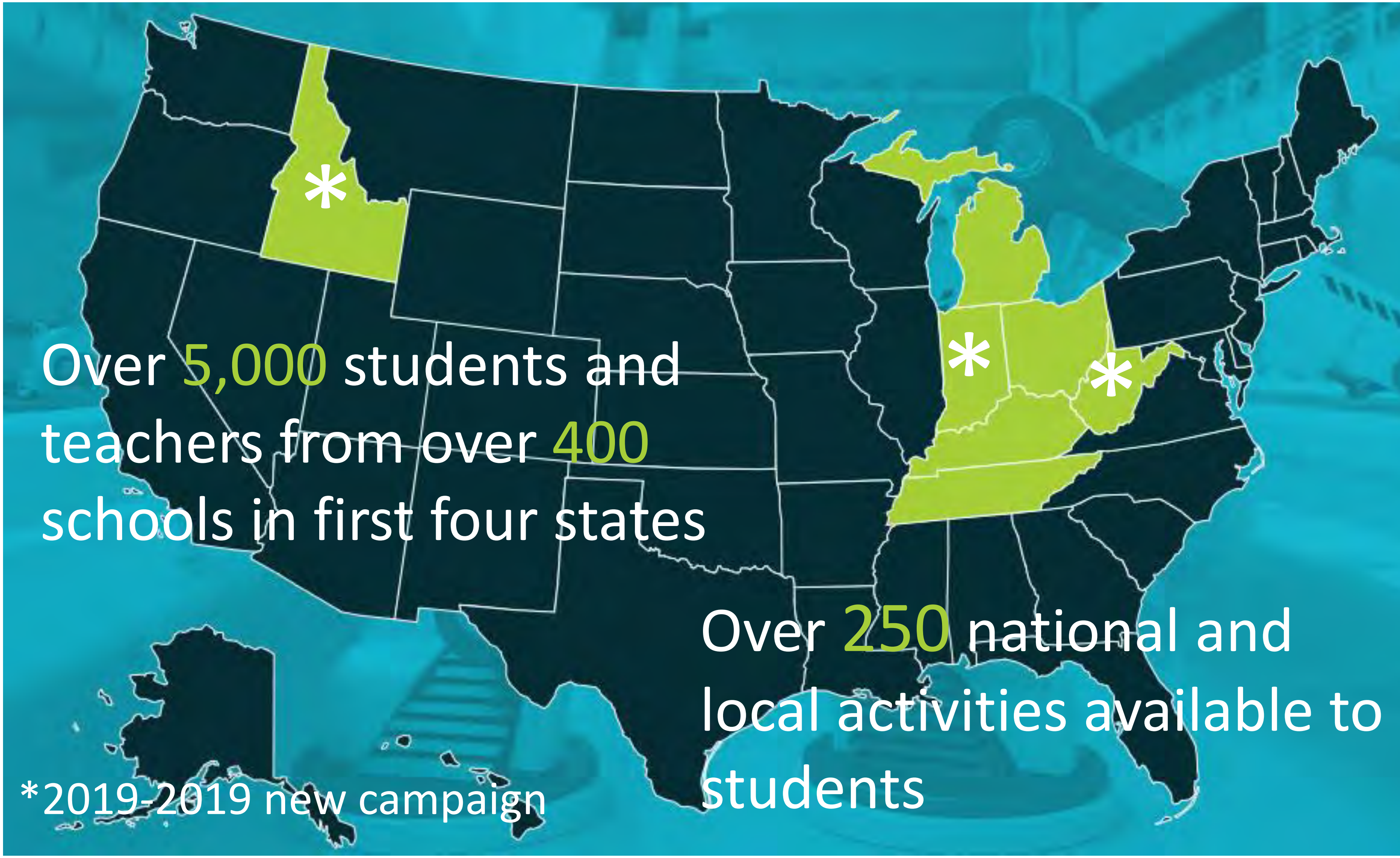
DISCOVERIES OF
Gibson

Gibson Guitar Tour
MIDDLE SCHOOL, HIGH SCHOOL, SCHOOLWIDE

Tennessee
SCIENCE
BOWL

Tennessee Science Bowl
HIGH SCHOOL, TEAM

Impact and Growth



Big Goals

- Students and schools gain ACCESS to high-quality learning opportunities in STEM and manufacturing
- Students gain TECHNICAL and NON-TECHNICAL EMPLOYABILITY SKILLS
- Campaigns build LEARNING ECOSYSTEMS by linking and leveraging disparate programs, activities and partners
- We create a PRO-MANUFACTURING mindset

Why?

Why did lift design and implement MakerMinded? Why is it a ManufacturingUSA responsibility?

- To build and educated and skilled manufacturing workforce
- To strengthen and support the Defense Industrial Base

Toward the Army's Science and Technology Career

Successful First Steps from the Army's Science and Engineering Apprenticeship Program for High School Students

Justin Wang

Chantilly High School, Virginia

How I got here – my education

- Twelve years of public-school education
- Currently a rising senior at Chantilly High School, Fairfax County, Virginia
- Applying for colleges!
- Most likely to study electrical engineering, applied physics or mechanical engineering

How I got here – spring of 2017

- Are unexplainable lab results always due to "instrumentation error?"
- Is that the real lab experience?
- Wanted to know what STEM research is like in a real lab
- AEOP's Science and Engineering Apprenticeship Program (SEAP)
- Will they take me? I really don't have much to offer!

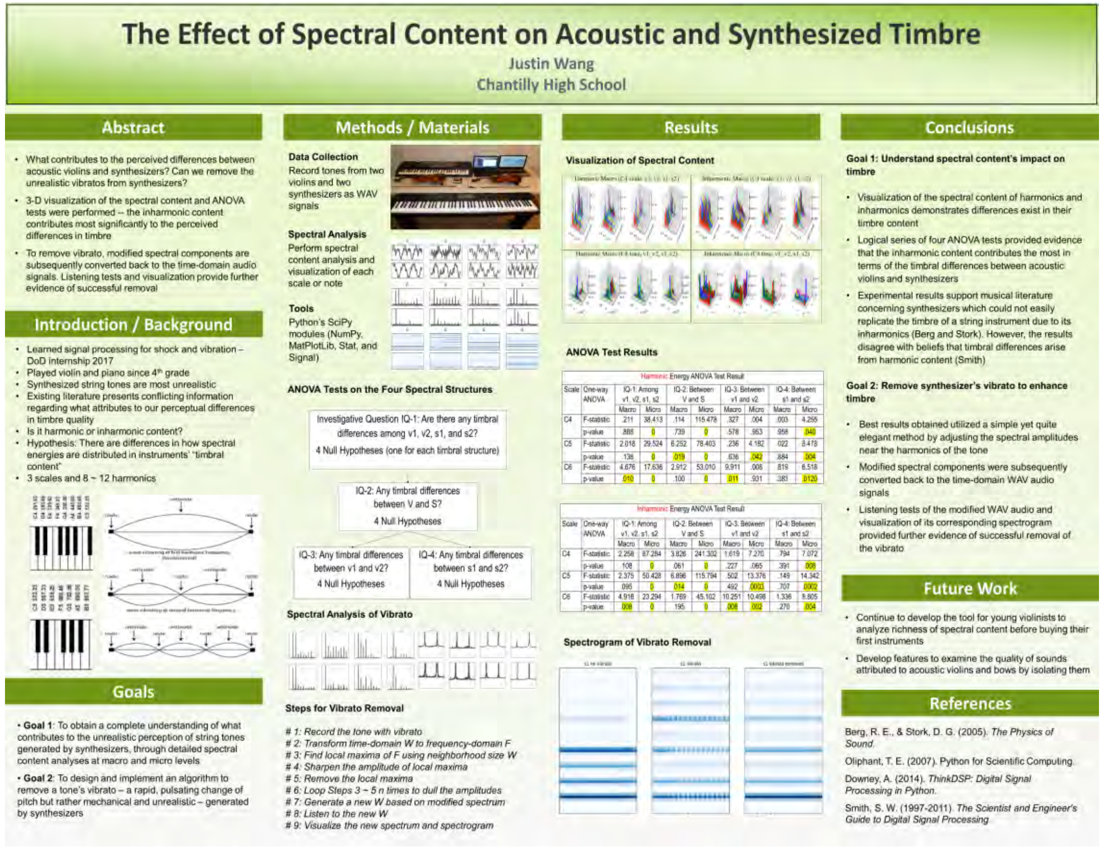
ARMY EDUCATIONAL OUTREACH PROGRAM

A turning point – summer of 2017

- ARL and my mentor took me!
- Assignment: port Matlab-based shock-and-vibration toolbox into Python
- Mentor taught me about basics of signal processing
- Solid 8 weeks of work wrestling with Python
- At the end of summer, started working on a sound-puzzle that mystified me for more than 8 years

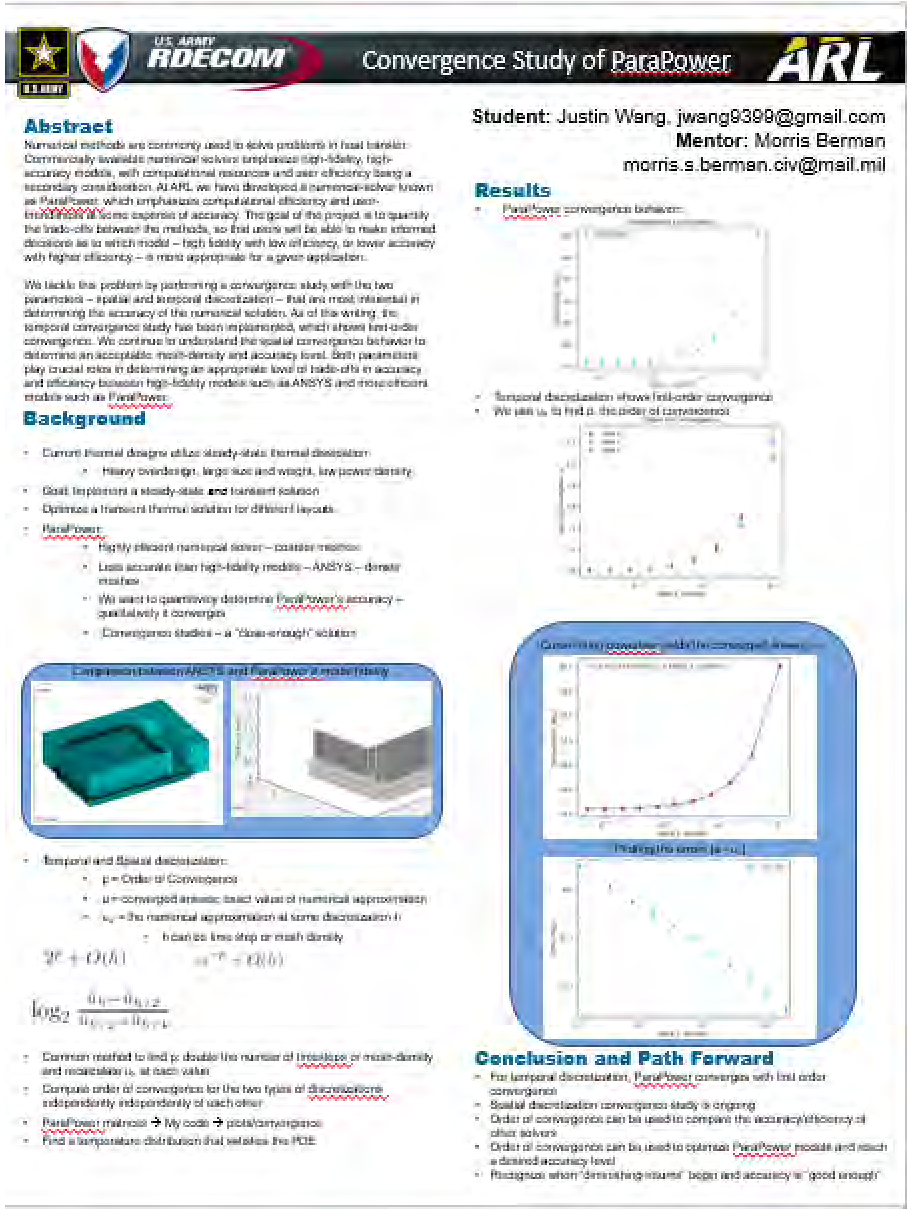
Many pleasant surprises – my junior year

- Won grand prize at Northern VA Science Fair → Intel ISEF finalist
- Won 1st place at Virginia State Junior Science and Humanities Symposium (JSHS)
- Won 2nd place (physics category) at National JSHS
- Army S & T Symposium invited me to share my journey of science exploration (education outreach)



Back to ARL again – summer of 2018

- Concerned about congressional budget; glad to be back
- Worked on a project developing a self-cooling chip
- Used last summer's shock-and-vibration toolbox efforts to simplify data handling this summer
- My contribution: convergence study of heat transfer from temporal and spatial perspectives
- Have learned tremendously, again



Reflection – 16 weeks of internship at ARL

- No better way to spend the two summers
  - Sense of responsibility
  - Use of public transportation!
  - Improve my technical skills
  - Meet other like-minded high schoolers, undergraduates, and graduate students
  - Clear my doubt regarding “instrumentation error”
  - **Meaningfully contributed to my mentor’s project**
- Solidify my selection of an engineering career
  - Engineering physics or electrical engineering

Reflection – 16 weeks of internship at ARL

- Remove any doubt whether math and physics are essential
  - See how they are used in a real lab
  - Use of instrumentation
  - Math modeling & model comparison
  - Heat transfer and phase change materials
  - Data processing and programming
  - Use of HPC systems – HPCMP ORS
- I really like the staff at ARL
  - They treated me like I am one of them
  - Hope to come back to intern for four more summers while in college

Reflection – DoD-sponsored JSHS competitions

- Competition format encourages communication
  - Written & oral
  - Judges are college professors or experts in the judging field
- Competition categories
  - Environmental, biomedical, life, medicine, engineering, math & computer, physics, chemistry
- Great to see so many like-minded future scientists
- Speakers and panelists for the National JSHS were fantastic
- Toured many DoD facilities

Where can I go from here – back to school

- None of the above could be possible without
  - AEOP: SEAP & JSHS & **ARL**
  - Time and energy my mentor spent on me
  - ARL colleagues' open arms & great projects
  - Countless people from ARL and AEOP
- 8-week is really too short
  - Getting momentum to contribute around week 6
  - Almost time to wrap up!
  - But I have not finished the assignment yet
  - May I stay a bit longer?

Extending beyond an 8-week apprenticeship

- Recalled past conversations with students who participated in science competitions
  - I explored a very simple idea of my own
  - Many other students continue investigations from larger projects originated from government or university research labs
- Is it possible to extend duration of the internship beyond summer?
  - Benefit of the mentor's project and the apprentice
  - Guest researcher?

Parting words

- SEAP and JSHS opened my eyes to the world of STEM lab career
- ARL has changed my future prospect
- Grateful for my ARL mentor-and-colleagues' guidance and support
- Hope to participate in 2019 DoD-JSHS competition
- Look forward to coming back to ARL for college internships:
    - DoD's SMART Scholarship for Service Program
    - AEOP's URAP
    - AEOP's CQL
- I plan to be back to present a technical topic at a future Army S & T Symposium & Showcase!

Warrior Performance Platform for U.S. Navy

Leveraging Best-of-Breed Human Performance Tracking and Analytics Technology To Enhance Navy's Physical Fitness, Wellness, and Nutrition Capabilities

Partners In Human Performance

JAKE REPANSHEK

Jake Repanshek is an experienced technologist with 14 years' experience leading and executing programs and projects for DoD and federal customers. As *tiag*'s Director of Solutions and Technology, he oversees *tiag*'s internal IT investments and works with senior leadership to develop and execute the company's innovation strategy. He serves as facilitator and technical solutions lead for *tiag*'s Technology and Innovations Strike Team, comprising highly specialized *tiag* innovators who develop cutting-edge technologies that enhance and elevate customer missions.

KEVIN DAWIDOWICZ

Kevin Dawidowicz is the co-founder and President of CoachMePlus. In his role as President, he is responsible for ensuring a unified strategic vision for the management team, along with spearheading partnership efforts. He boasts over 15 years of working side-by-side with strength and conditioning coaches and sports scientists to build high-performance software systems for tracking and managing human performance.

WP2 Overview

Human performance tracking and analytics to enhance physical fitness, wellness, and nutrition capabilities. WP2 platform monitors Warriors throughout the readiness cycle, informing key command decision makers to support mission and training adjustments. Holistic evaluations can be tailored to reflect each command's unique requirements. Provides the ability to uncover trends, develop insights, reduce risk, and customize training programs. Leaders measure human performance based on preparation, physical fitness, strength and capabilities. Facilitating individualized training and readiness.

Advancing Proactive Human Performance Management

- Amplifies effectiveness and advances in human-performance
- Delivers the information at the right time to the right person
- Enhances military readiness and performance
- Promotes improved performance through real-time individual assessments
- "Just in Time"…"Ready to Perform" decisions
- Secure, accreditation-ready platform

Speed of Information

- Advanced analytic capabilities
- Centralized data
- Centralized management
- Centralized workflow features
- Customized dashboards
- Increase accountability
- Secure, accreditation-ready platform
- Rapidly discover and locate outliers

Informs Performance Decision-Making

- Immediate and long-term data for "ready to perform" decisions

Precision vs. Subjective Assessment

- Assesses key performance indicators of entire units and each individual warrior's capability to advance mission

Benefits

Benefits

- Warriors are operationally ready
- Take immediate action
- Store fitness tests, medical information, performance analysis, profiles, testing, training programs and training
- Reduce stress-related injuries
- Manage injuries
- Keep warriors at their best
- Enables customize training programs
- Determine risk factors
- Curtail chronic/overuse
- Centralized Repository
- Automate Reporting

Measures of READINESS

- TRAINING
- STRENGTH & CAPABILITY
- PERFORMANCE

- INTERNAL LOAD: CARDIO, RPE
- EXTERNAL LOAD: PERFORMANCE STATS
- FATIGUE
- HYDRATION
- STRESS
- SLEEP & RECOVERY
- PAIN & SORENESS

Non-Combat Injuries Reduce Readiness

- Physical Training and sports-related activities account for 90% of musculoskeletal injuries (MKSI)
- MKSI accounted for 2.4 million visits to military medical treatment facilities and $548m in direct patient care costs
- Traumatic overload and overuse in lower body accounted for 4.8 million of the 11 million annual limited duty days related to injury
- 80% of MKSI are considered overuse in nature
- Majority of MKSI in the deployed setting are non-battle related
- 34% of deployed troops experience non-combat MKSI

(Source: American College of Sports Medicine, Vol 13, No 1. Jan/Feb 2014, Consortium for Health and Military Performance and American College of Sports Medicine Summit)

Large Population of Non-Deployable Soldiers

- As of late 2015, Army Active component had 50,000 non-deployable Soldiers
- Represents ~10% of total active force
- “Having 50,000 non-deployable active soldiers is comparable to three of the Army's 10 active combat divisions”
- Roughly 37,000 of the 50,000 non-deployable soldiers are unavailable for medical reasons

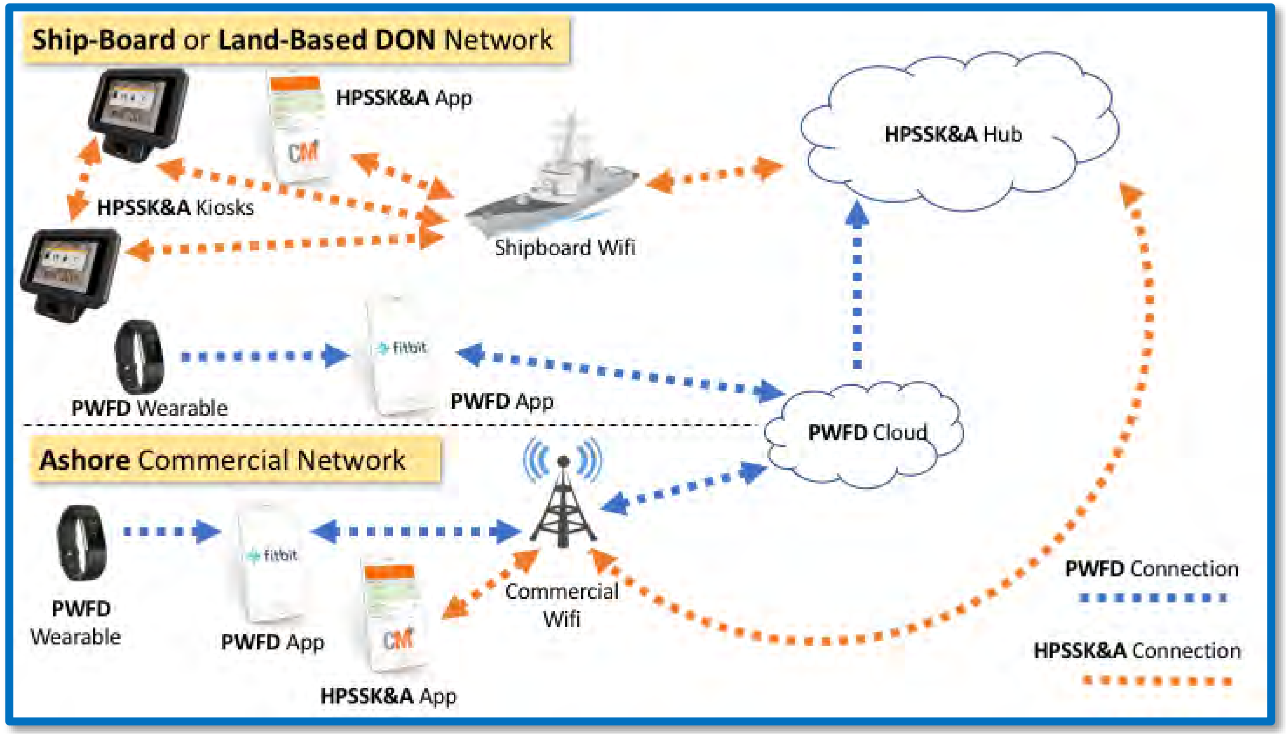
(Source: “Army Has 50,000 Active Soldiers Who Can't Deploy, Top NCO Says”, Miltary.com, 11/15/15)

The Army estimates $4 billion is spent each year due to injuries, non-deployable Soldiers, accidents and other health-related costs.

Human Performance Self-Service Kiosk & Application

- Human Performance Self-Service Kiosk and Application, (SBIR N171-079), sponsored by the US Naval Supply Systems Command

- Builds upon core WP2 functionality, but adds:
    - Nutrition
    - Ruggedized Touchscreen Kiosk
    - Support for Austere Environments
    - Shipboard Integration
    - Data Source Integrations (Naval Operational Fuel and Fitness System, MyPlate and Go for Green)



- Supports app-based access from personal mobile devices, as well as data integration from select wearables

- Completed Phase I, down selected for Phase II. Kickoff in August 2018.

Challenges and Way Forward

Challenges

- Cybersecurity Considerations
  - Cloud hosting/SaaS model
  - Personally Identifiable Information
  - Protected Health Information
  - Reciprocity between organizations
- Synchronization in Auster Environments
  - Shipboard
  - Theater
- Adoption/Buy-In

Future State

- Advanced Analytics / Machine Learning
  - Predictive vs. Reactive
- Mental/Behavior Health Applications
  - Post-traumatic Stress Disorder (PTSD) Event Detection
  - Traumatic Brain Injury Assessments
- External Integrations with Systems of Record

Questions

Backup Slides

Value Proposition For The Military Community

In America's fight against terrorist groups and ongoing threats to national security, the Military is deployed to 70% of the world's countries. Enhancing the intensive training and fitness of these warriors, now there's a technology to help ensure their endurance and survival.

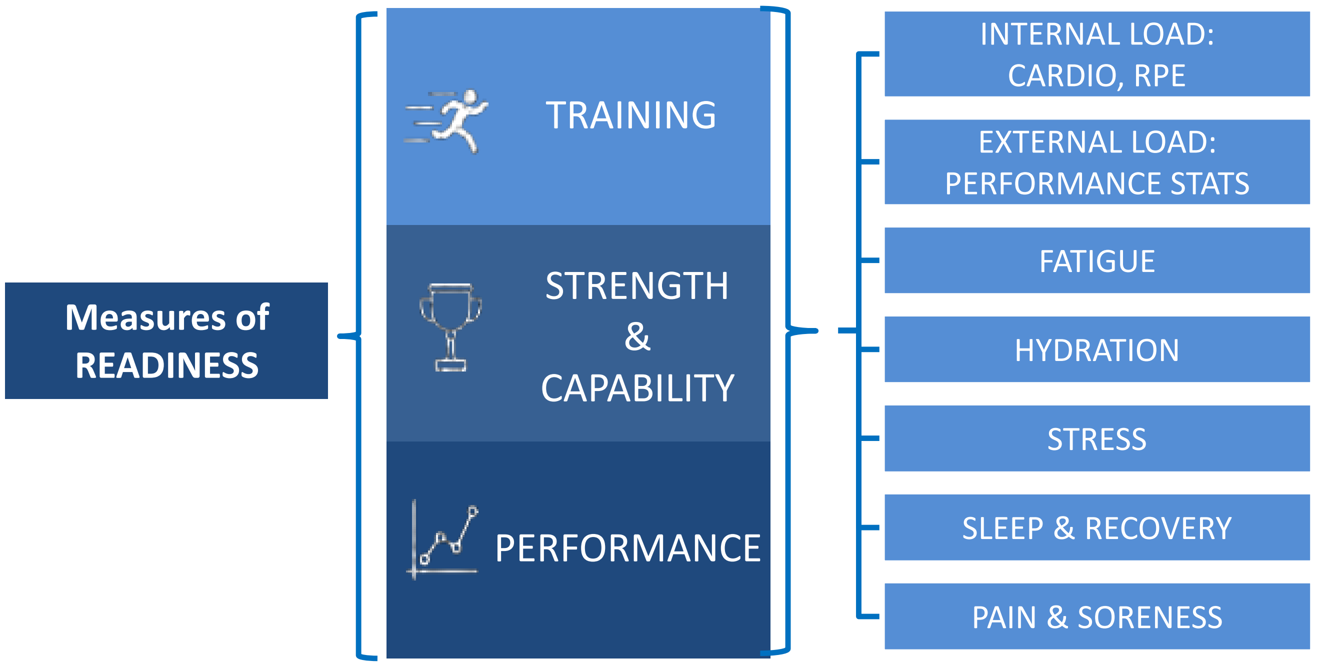
Continually evaluating, adjusting and optimizing military training, performance and readiness directly correlates with . . .

ensuring the strength, endurance and survival of military units in the fight against threats to America's security.

Leveraging Applied Science and Technology

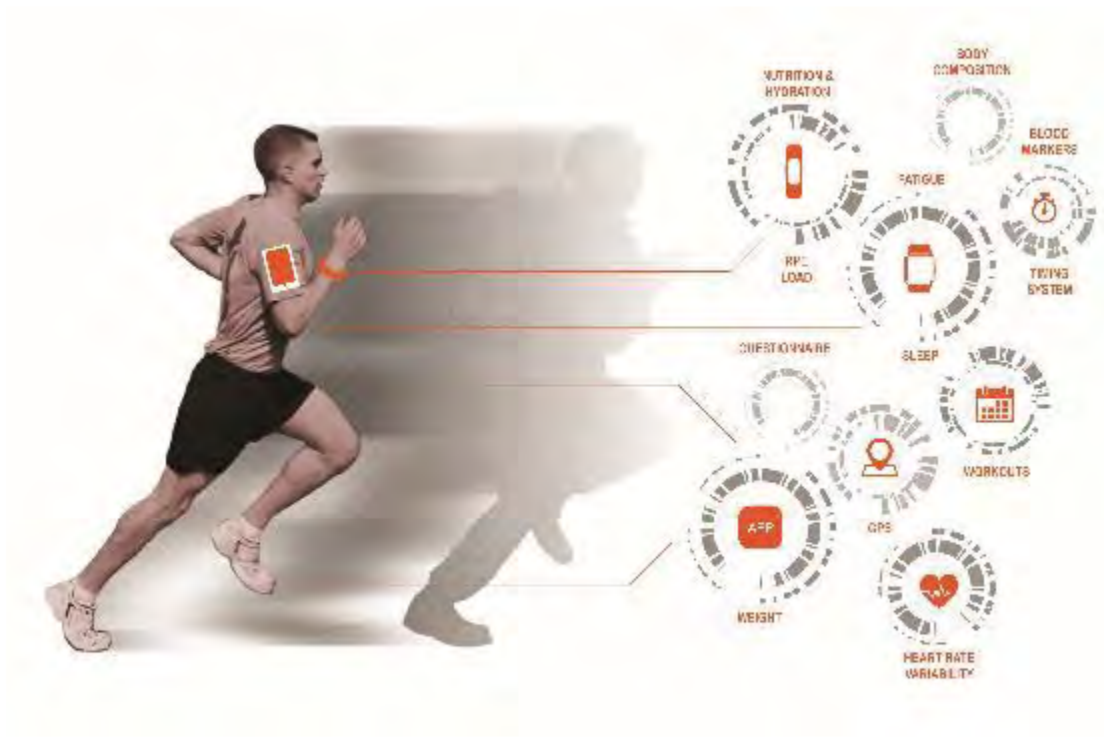
Advancing proactive performance management from training through deployment, WP2:

- Is powered by applied science and next generation human performance analytics
- Leverages the technology of 60+ wireless, wearable devices, integrates all data into one centralized platform for enhanced overall warrior analysis
- Fuses tiag's expertise in data analytics, telemedicine and cutting-edge health IT solutions
- Incorporates decades of lessons learned in military communities and professional sports arenas
- Integrates the CoachMePlus performance-optimization solution used by major teams across the NFL, NHL, MLB, NBA, NCAA, MLS, CFL and military



Centralized Management of Data

High-Performance Data for enhanced military readiness



Speed of Information

- Centralized location for performance data, all in one place
- Enterprise application includes front office, warrior profiles, reporting, permissions and security features
- Centralized workflow features warrior app, unit access point and additional workflows
- Individual, customized dashboards and advanced analytic capabilities to meet specific command needs

Informs Performance Decision-Making

- Immediate and long-term data for “ready to perform” decisions

Precision vs. Subjective Assessment

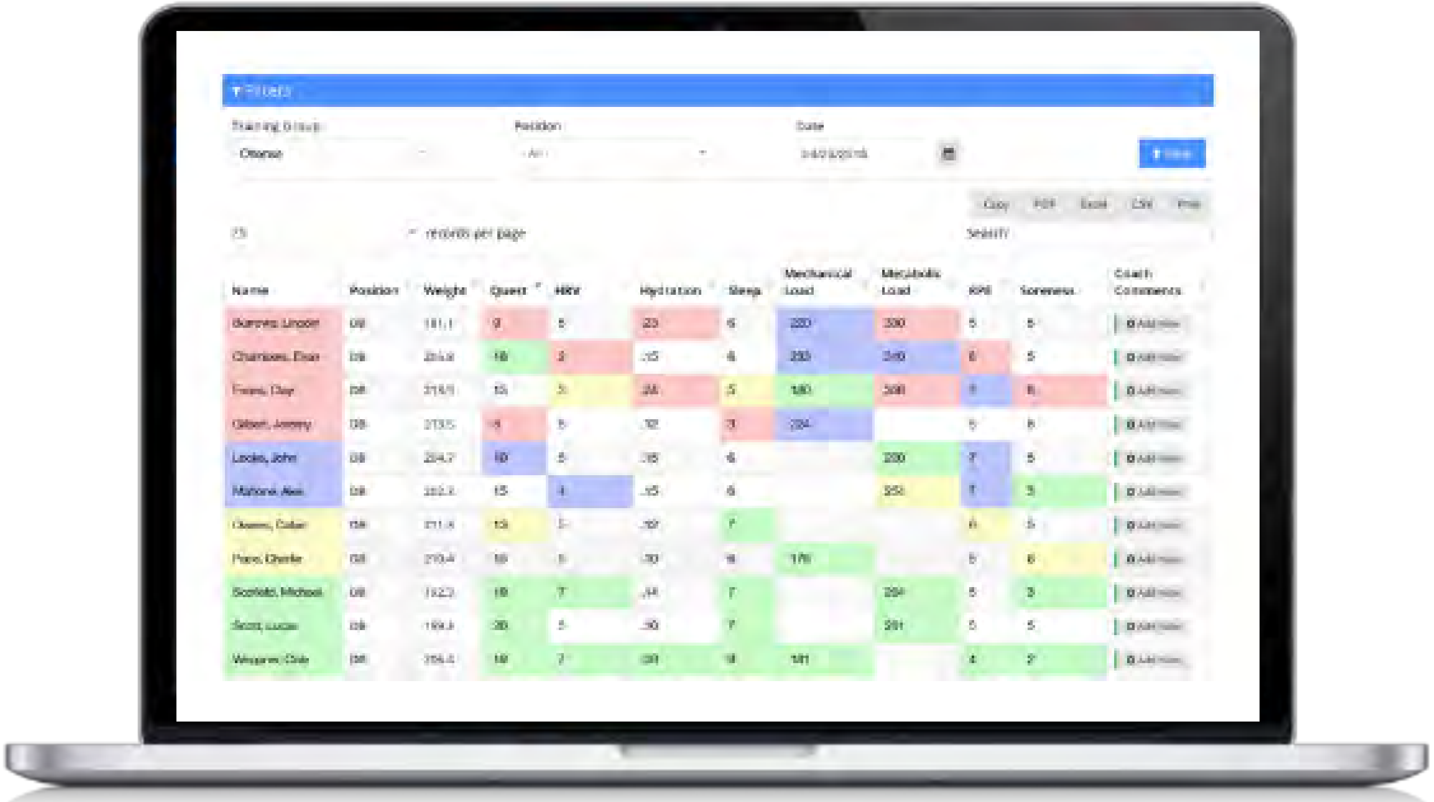
- Assesses key performance indicators of entire units and each individual warrior’s capability to advance mission

Individual Dashboards

SPEED OF INFORMATION— creating a “performance gestalt”

Unit Reports

SPEED OF INFORMATION— just-in-time, "ready to perform" decisions



"It allows you to stay ahead of the curve and be smarter in your decision making, which allows you to keep your players healthier and train them harder."

-Director of Olympic Sports Strength and Conditioning, Clemson Univeristy

Individual Insights

APP-BASED ACCESS

Promotes improved performance through real-time individual assessments

- Evaluates all objective and subjective warrior information
- Records all testing, resistance training and joint ROM data in one location
- Shares individual performance information back to the warrior as an educational tool
- Prevents mission injuries through increased understanding of individual metrics
- Motivates warriors with improved insights into their own performance statistics
- Highlights required adjustments from improved hydration to increased recovery time

Unit Access Point

CENTRALIZED WORKFLOW

"If you choose to integrate technology into your strength and conditioning program, you can benefit from the ability to assign and track workouts and monitor hundreds of [individuals] as well as update training programs throughout … using phones, tablets, etc."

-Head Strength Coach, National Strength and Conditioning Association

Amplifying Training Effectiveness

Significantly enhances military readiness and performance

- Focuses analysis and insights on human performance metrics most applicable to the DoD
- Monitors key indicators of warrior fitness, health and capability, maximizing real-time and historical data within one centralized system
- Enables leadership and instructors to customize training programs that push warriors to top performance, while curtailing chronic/overuse and stress-related injuries

Amplifies effectiveness and advances in human-performance research

- Delivers capability to uncover trends, develop actionable insights, reduce risk and prevent negative outcomes
- Provides holistic evaluations tailored to reflect each command's unique requirements

Delivers the right Information at the right time to the right person

- Empowers leadership to continually evaluate, adjust and optimize training, performance and readiness of deploying units
- Informs key command decision makers to support mission and training adjustments

Accreditation ready

Robust security and permissions management system for units and individuals

Provides secure, 24/7 information access

All information is encrypted in transit and at rest

Maximizing Mission Readiness

Seamlessly integrates wearable data with applicable information

- Aligns medical and human performance staffs
- HRV and hydration data reflected on the same page
- Includes manual measurements such as girth measurements and caliper pinch testing

Allows instructors to adjust exercise programs and assign back to warriors

- Includes exercise types, videos and measurable metrics
- Tracking automatically updated as warriors enter info when completing exercises and programs
- Provides ability to communicate with individuals or units publicly or privately

Provides cross-data reporting that other systems cannot

- Precision Performance builds tests for the unit, replacing difficult-to-share spreadsheets
- Allows analysis at individual level and also against unit-wide performance standards
- Import data from across multiple commands to provide leadership with overall readiness synopsis
- Empowers leaders / instructors to spend more time with warriors and less time in spreadsheets

Cutting-edge Expertise

***tiag* brings a history of transformational leadership advancing military medical science and telehealth technology**

- Leads web application efforts at DoD's National Center for Telehealth &Technology (T2)
- Delivers cutting-edge health IT solutions (e.g., VA's open-source EHR)
- Developed the Army's Research Management Enterprise System, providing autonomous big data management across numerous laboratories

Delivering end-to-end individual training and readiness solutions for DoD, WP2 leverages tiag's demonstrated military experience and technical expertise

- Quick, all-in-one-place information access empowers leaders to determine risk factors and take immediate action
- Warriors are operationally ready and less likely to sustain injuries that keep them out of the fight

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

Biophysics Based Measuring & Modeling of Social Dynamics

Dr. Lisa Troyer

Program Manager, Social & Behavioral Sciences, Life Sciences Division

Army Research Office/Army Research Laboratory

22 AUG 2018

MEASURING & MODELING SOCIAL DYNAMICS

Why Army Research on Social Dynamics?

- Conflict is costly in terms of lives, resources, future opportunities, optics
  - Conflict is an inherently social problem
- DoD is first-responder in humanitarian crises, with little advanced warning about where those crises will occur – cultural, normative, political, economic context
- Increasing evidence of severe potential of **non-kinetic threats**:
  - Adversarial disruption of: Economic, Political, Religious, Cyber, Health
- Social systems reflect complex, multilevel, multiplex interdependencies
  - We need to think “from (deep within) cells-to-societies”
  - We need to think about interfaces among physical, natural & social systems

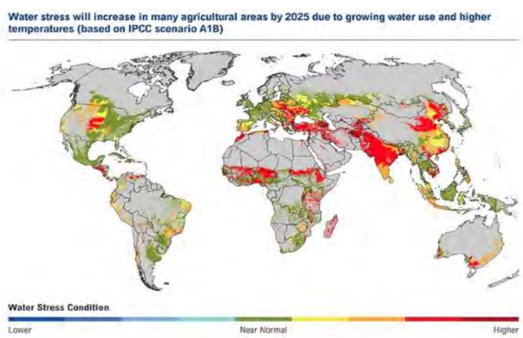
From Cells to Societies

MEASURING & MODELING SOCIAL DYNAMICS

Potential Army Payoff of Social Science

- What if the Army could…
  - Determine the next region of sociopolitical instability (and the one after that... and the one after that…)?
  - Predict where, when, why, how the next violent extremist group will emerge?
  - Advance security by managing threats to social systems arising from disturbances in natural and physical environments?
- Addresses Army Modernization Priorities
  - Soldier Lethality – esp. Situational Awareness
- Addresses National Defense Strategy
  - Countering Coercion & Subversion, Enhance C4ISR Capabilities, Advance Overmatch in Global Operations

Army Leadership in Basic Social Science Research



MEASURING & MODELING SOCIAL DYNAMICS

Why Social Science is Hard (Not Soft)

- For every outcome there is an "intuitive" explanation
    - Once you explain, it all makes sense – but there are multiple explanations that make sense
- Social science is hard because most social phenomena:
    - Are emergent from interface of shifting social, physical, and natural dynamics,
    - Which occur over large spatial and temporal dimensions
        - Change in different spaces, different points in time impacts others with enormous cascading effects
        - Are difficult to investigate in controlled settings,
    - Are challenging to measure at collective levels

But… Advances Across DoD Are Generating Promise

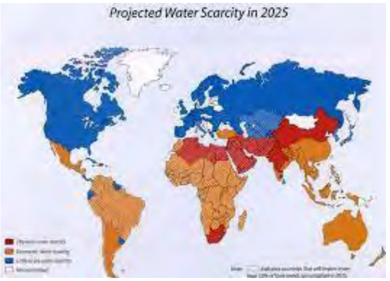
MEASURING & MODELING SOCIAL DYNAMICS

How Army Is Approaching Social Science

- Social Dynamics Underlying Social Conflict Are Not Accurately Modeled; Validated Basic Scientific Theory Is Lacking
- Current state-of-the-art research on social collectives is insufficient:
  - Depends on aggregation of individual behaviors, which generates erroneous predictions
  - Does not account for relational impact of actors and groups on one another or impact of natural and physical (built) environments on social collectives
  - Research methods relying on individual recall are inadequate, generate bias, and results are rarely replicated
  - Models rely on invalid statistical assumptions that lack recognition of how social processes evolve and scale, lacking predictive capability
  - Peer-reviewed research is seldom validated, replicated, or reproduced to establish confidence in existing tools/knowledge

Emergence of Large-Scale Social Conflict Is <u>NOT</u> a Function of Simple Aggregation of Individual Human Behavior

MEASURING & MODELING SOCIAL DYNAMICS



Water Scarcity Models - 2025

ISIL damns prevent access to Euphrates to exert control over civilians

How Army is Approaching Social Science

- Impacts of Changes among Natural, Physical (Built), and Social Systems over Time, Space, and Levels of Analyses are Difficult to Measure
  - Building integrated validated data archives that measure interdependencies among natural, physical, and social
  - Developing measures of social conflict to account for interdependencies among social collectives, natural environments, and physical infrastructures
  - Addressing gaps in knowledge of spatial and temporal cause-effects across social, natural, and physical systems
  - Improving standards for assessing integrity (e.g., reliability, validity) of measures of social dynamics

Impact of Changes in Natural & Physical Systems on Social Dynamics is Neglected

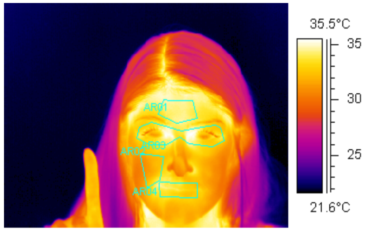
Non-state adversarial groups seize mineral resources in fragile states with local support in resource-stressed environments

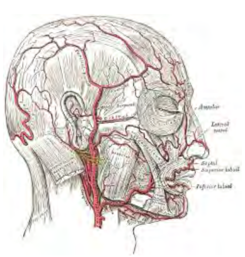
U.S. ARMY
RDECOM
ARL RESEARCH LABORATORY

MEASURING & MODELING SOCIAL DYNAMICS

Success Stories: New Approaches to Sensing Social Dynamics through Objective Measures – Micro Sensors

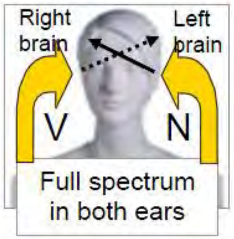
- Advances in biophysiological measures & models of human ***SOCIAL*** dynamics
  - Vocal spectrum, thermography, brain imaging, pupilometry
    - Document: ***Social*** influence, diffusion of emotion in a collective, propensity for conformity, in-group empathy
  - Epigenetic predictors of social behavior
    - Genetic bases for aggression triggered by ***social*** conditions
- Basic scientific evidence that social dynamics are embodied in physiological and biological processes

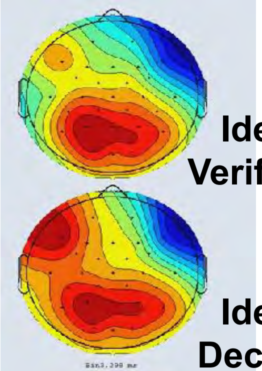




N = nonverbal signal (vocal frequencies < 350 Hz)

V = verbal signal (vocal frequencies > 550 Hz)





Identity Verification

Identity Deception

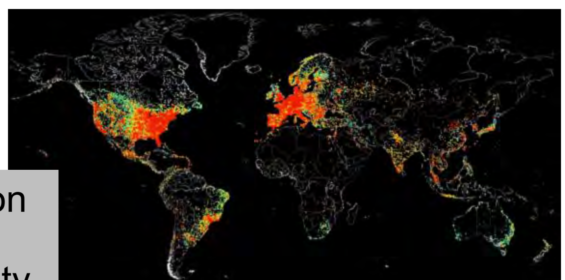
New Sensing Technologies to Link Individual to Collective Dynamics

MEASURING & MODELING SOCIAL DYNAMICS

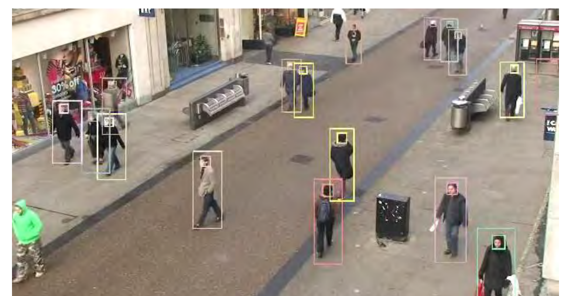
Success Stories: New Approaches to Sensing Social Dynamics through Objective Measures – Macro Sensors

- Investment how macro sensing approaches enable tracking of shifts in large-scale collective behavior
  - Utility use
  - Geo-mapping of resource changes
  - Satellite imaging of correlates of social activity
  - Computer visioning to track social clustering
  - Internet & cellular loads to identify activity shifts
- Develop integrated archives from macro sensor data to facilitate development of measurement & analytic research

Satellite tracking of population movement to enable new models of migration



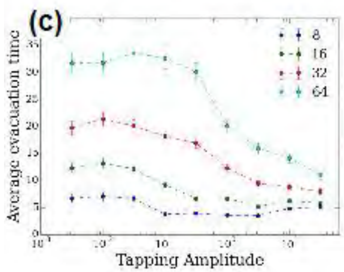
Tracking population activity through Internet connectivity



Computer visioning to track crowd dynamics – identifying cliques and hostile collectives

New Sensing Technologies Create Opportunities to Develop Measures of Population Dynamics

MEASURING & MODELING SOCIAL DYNAMICS

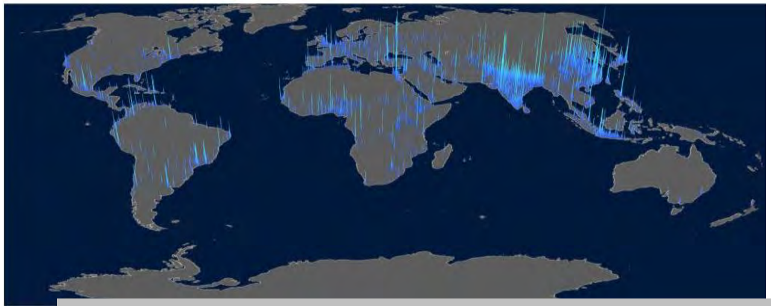


Modeling effects of sensory inputs on crowd behavior

Success Stories: New Approaches to Modeling Collective Dynamics & Complex Systems

- Investments in research to develop complex systems models extending research on macro-sensing to develop new predictive theories of social dynamics
  - Macro-models of real-time population ecologies based on geo-spatial sensing
  - Development and validation of swarming, flocking, herding models inspired by physics & biology
  - Predictive models of social dynamics drawing on epidemiology (e.g., mortality modeling of large-scale threatening events)
  - Value-chain models to identify resource interdependencies across time and space

Enabling New Models to Predict Emergence of Social Conflict



Visualization models of expansion of built up areas of earth over last 40 years

MEASURING & MODELING SOCIAL DYNAMICS

Ongoing Challenges

- Development of social science theory, measurement, modeling
- Data management (when is too much, too much?)
  - Make it manageable for the operators/analysts/decision leaders
- Knowledge vs. Tools
  - Transition is EXCEPTIONALLY difficult to track & measure in social science – mostly in the form of knowledge about how social systems operate
  - Tools come with risk of oversimplification, user bias
- Improving the Pipeline
  - Training next-generation of defense social scientists
    - "All-hands" approach – improve involvement of underrepresented groups
  - Enhancing multidisciplinary team approaches to social science
  - Enabling global science through support of international collaborations

Human Groups Are NOT Out of the Loop:

Designers, Operators, Interpreters, Decision-Makers

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

Biophysics Based Measuring & Modeling of Social Dynamics

Dr. Lisa Troyer

Program Manager, Social & Behavioral Sciences, Life Sciences Division

Army Research Office/Army Research Laboratory

22 AUG 2018

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

Building a foundation for MUMT

Jeff Ernat

Team Leader for Autonomy Teaming

RDECOM, TARDEC, Ground Vehicle Robotics (GVR)

22 AUG 2018

BUILDING A FOUNDATION FOR MUMT

Logistic Resupply

Autonomous Ground Resupply

Develop and demonstrate an improved and optimized distribution system that integrates new & emerging technologies across the full spectrum of operational and tactical supply movement operations.

Expedient Leader Follower

Rapidly delivery and issue 70 leader follower enabled PLSs to Soldiers for a one year Operational Technical Demonstration (OTD) starting 4QFY19.

Robotic Combat Vehicles

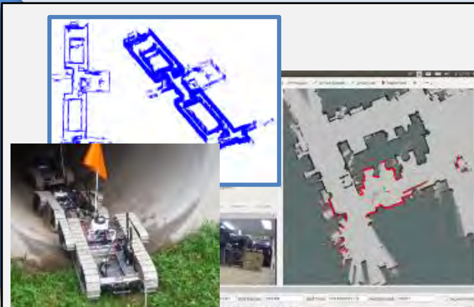
Combat Vehicle Robotics

Develop/integrate technologies that enable scalable integration of multi-domain robotic and autonomous system capabilities teamed within Army formations supporting all combat warfighting functions.

Future Manned / Unmanned Teaming Formations

Built on Open Autonomy Architecture (AGVRA)

Small Robotics for Urban / Subterranean



Development of capabilities to support urban and underground operations such as unmanned complex tunnel investigation, CBRNE missions and reconnaissance.

CAPABILITY TO SOLDIERS SOONER

Autonomy Architecture enables getting hardware into Soldier's hands with incremental software capability improvements over time.

Logistic Resupply

Issue two companies (60 PLS Trucks) with Leader Follower capability to soldiers for 12 month operational evaluation.

Expedient Leader Follower

4QFY19	3QFY20	3QFY22
Increment I	***Increment II***	***Increment III***
Baseline Architecture Design & Build	**Additional Autonomous Behaviors**	**Advanced Convoy Behaviors**
✓ Modes (Leader Follower, Teleop)	• Modes (Augmented TeleOp, Waypoint)	• Modes (Augmented Waypoint)
✓ Assembly (Manual Line Up Vehicles)	• Assembly (Drive Past and Assemble)	• Assembly (Line Up in Depot)
✓ Formations (Column)	• Formations (Inverted T)	• Formations (Staggered Column)
✓ Reverse (Teleoperation and Manned)	• Trailers (Forward)	• Trailers (Forward & Reverse)
✓ GPS Denied (LOS to Leader)	• Reverse (Retrotraverse)	• Reverse (Retrotraverse)
✓ Turnaround (Vehicle K Turn)	✓ GPS Denied (Comms to Leader)	• GPS Denied (Know AO)
✓ Obstacles (Static & Large Dynamic)	• Turnaround (U Turn)	• Turnaround (U Turn with Obstacles)
✓ Dynamic Rerouting (None)	• Obstacles (Negative)	• Obstacles (Small Dynamic)
✓ AO (Primary & Secondary Roads)	• Dynamic Rerouting (Static Vehicle)	• Dynamic Rerouting (Moving Vehicle)
✓ Operations (Day and Night Driving)	• AO (Open & Rolling Terrain)	• AO (Trails)
• Weather (Light Rain/Snow/Fog)	• Operations (Black Out)	• Operations (PLS OMS/MP)
✓ Safe Harbor (Stop)	• Weather (Moderate Rain/Snow/Fog)	• Weather (Heavy Rain/Snow/Fog)
	• Safe Harbor (Pull Over)	• Safe Harbor (Limited path)

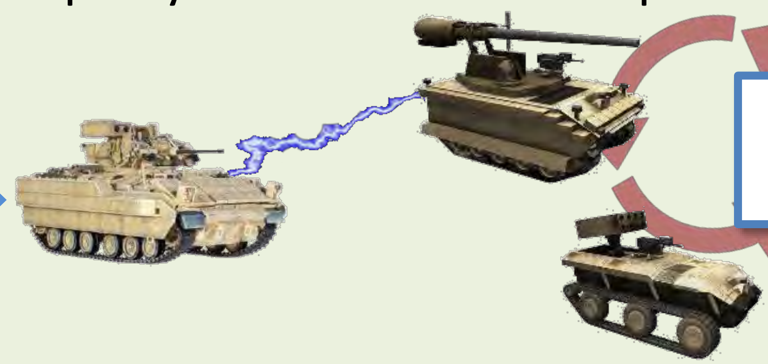
AGVRA

Autonomy Behavior "App Store"

Army does not have to re-buy autonomous similar capability for different platforms

20+ Other Platforms Demonstrated

Baseline capability will be built on for more complex tactical, weaponized systems



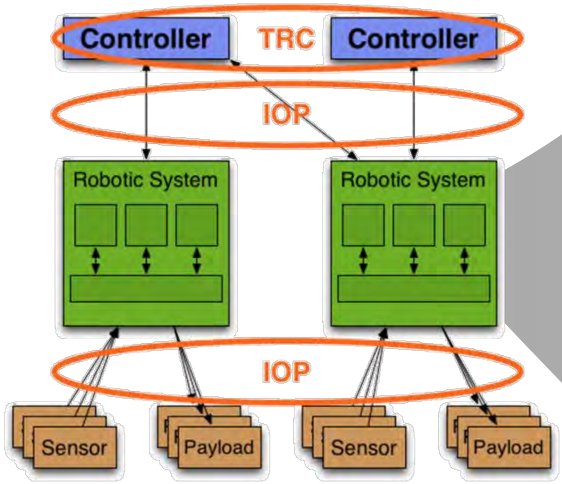
Combat Vehicle Robotics (CoVeR) **program will advance autonomous behaviors to enable mounted Manned Unmanned Teaming**

Robotic Combat Vehicles

OPEN MODULAR GROUND VEHICLE AUTONOMY

Autonomous Ground Vehicle Reference Architecture (AGVRA) - Set of guidelines to enable the robotics community to fulfill the Army's Robotic and Autonomous System (RAS) commonality objectives by establishing an affordable means to deliver advanced capability to the Warfighter by utilizing architectural best practices and standards.

Key standards for unmanned systems



Interoperability Profile (IOP) defines software massaging & hardware interfaces between major subsystems of unmanned ground systems utilizing existing standards

Autonomy Software Framework (ROS-M)

ROS is an open source software framework for robotic development that provides the following features to allow for modular software development:

Less time spent here *means* **More time to spend here**

\+

\+

\+

Plumbing
Flexible, node based communications infrastructure

Tools
- 3D Simulation
- Logging/Analyzing Sensor Data
- System visualization, etc.

Capabilities
Modular addition of capabilities by adding nodes to the system

Ecosystem
Large number of users actively contributing to ROS community

Ground Vehicle Robotics (GVR) Modular Software Approach (MSA)

- Defined modular autonomy software architecture for Army ground autonomous systems
- Success of this approach relies on strong government and industry collaboration developing interface standards at the appropriate level between applications.

- Library of GPR autonomy software (ITAR compliant) provided to industry through software distribution agreement (20+ outside entities have the software)
- Enabling competition at the software module level (prevents vendor lock, mitigates talent migration, enables gov't to capitalize on industry innovation)
- Common software framework/architecture to streamline test and evaluation process (Delta test for new capabilities rather than totally new system)
- Transition path for future capabilities such as AI / ML enabled autonomy

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

Taking new concepts for systems design and control from neuroscience to accelerate innovation in artificial intelligence

Kelvin S. Oie

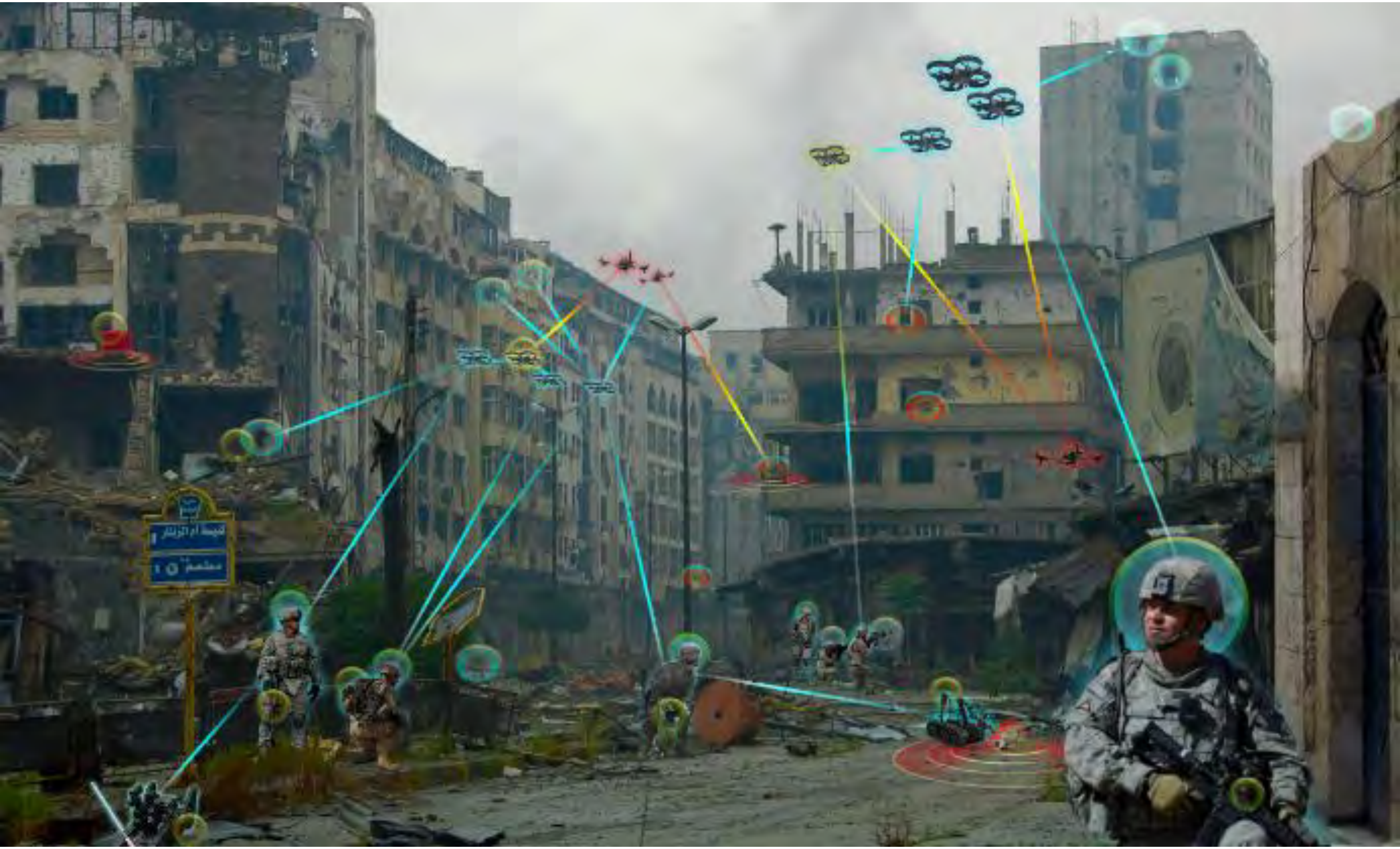
ARL Senior Campaign Scientist, Human Sciences

Human Research & Engineering Directorate

22 August 2018

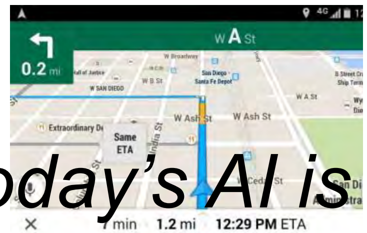
APPROVED FOR PUBLIC RELEASE

AI AND THE FUTURE BATTLE



AI IN THE CURRENT CONTEXT

Artificial Narrow Intelligence (ANI)



Artificial General Intelligence (AGI)

Today's AI is brilliant at very narrow competencies, whereas humans are good at pretty much everything.

- Dr. Sean Holden, Cambridge University (Doherty, 2016)

- clearly-defined, measurable tasks
- performance uncertainty is tolerable
- standard approaches don't work
- LOTS of training data is accessible

- ill-defined, difficult-to-measure tasks
- "human-like" performance is needed
- standard and ANI (?) approaches don't work
- Long experience may be necessary

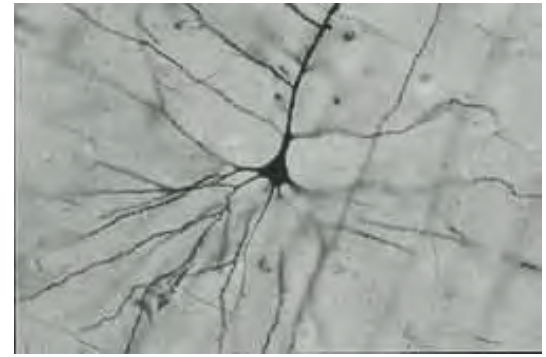
AI IN THE CURRENT CONTEXT

[N]arrow AI techniques, used to solve specific problems, will dominate AI application in the next 10 years, accounting for 99.5% of AI revenue between 2016 to 2025.

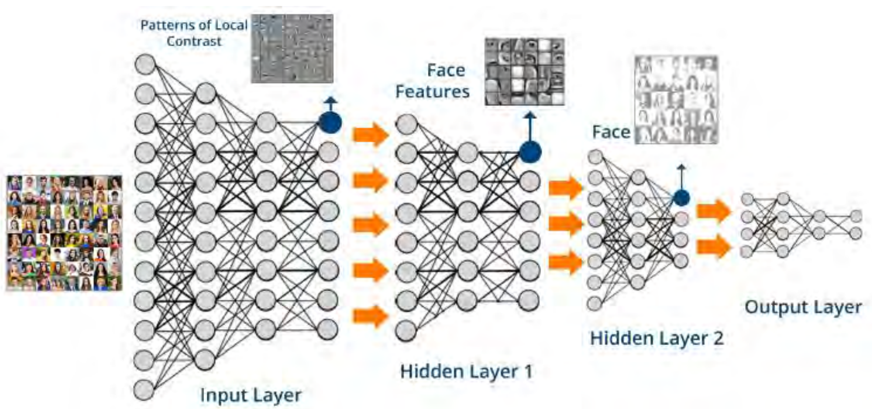
- Tractica (2016)

INSPIRED BY NEUROSCIENCE?

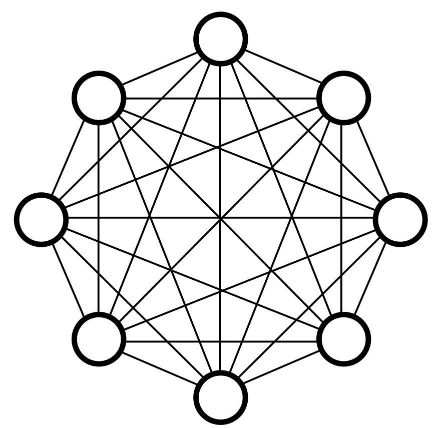
$$\tau_m \frac{du}{dt} = -\, u(t) + R\, I(t)$$

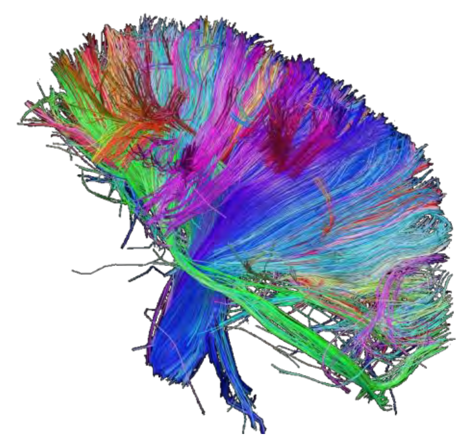


- Highly-simplified neurons
- Homogeneous neuron types



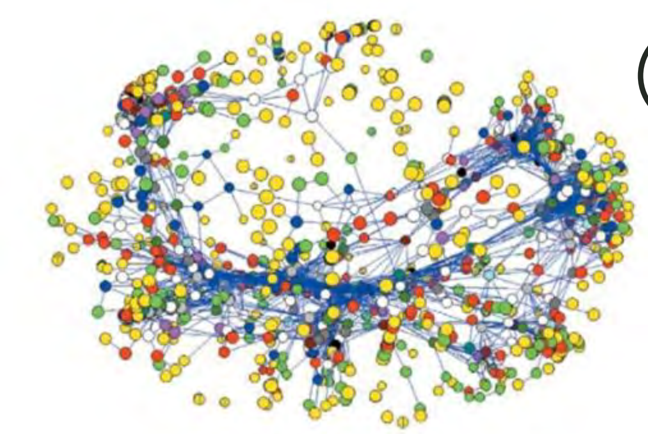
- Hierarchically organized
- Quiescent
- Highly connected

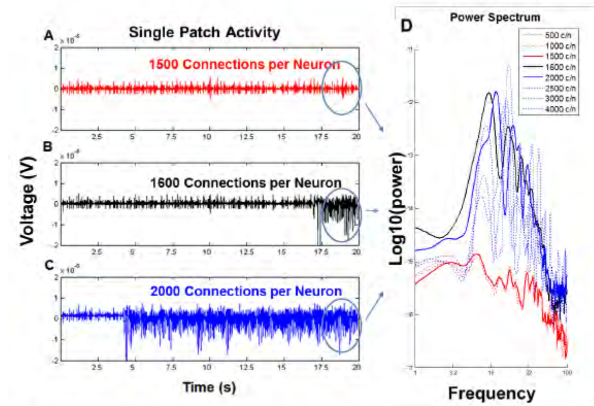




BECOMING MORE "BRAIN-LIKE"

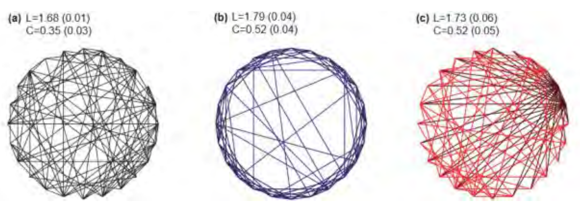
(see Crone et al. poster at this conference)





A-C. Time series of simulated model local-field potentials with increasing average connectivity. D. Power spectra of last 2.5 s of simulated model local-field potentials.

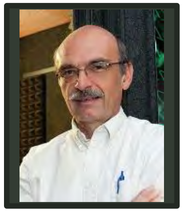
1 connectivity



2 dynamics

(see Felton et al. poster at this conference)

PROJECT TEAM



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Melvin A. Felton, Jr.[3]
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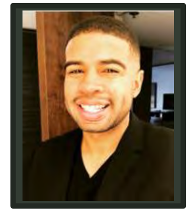

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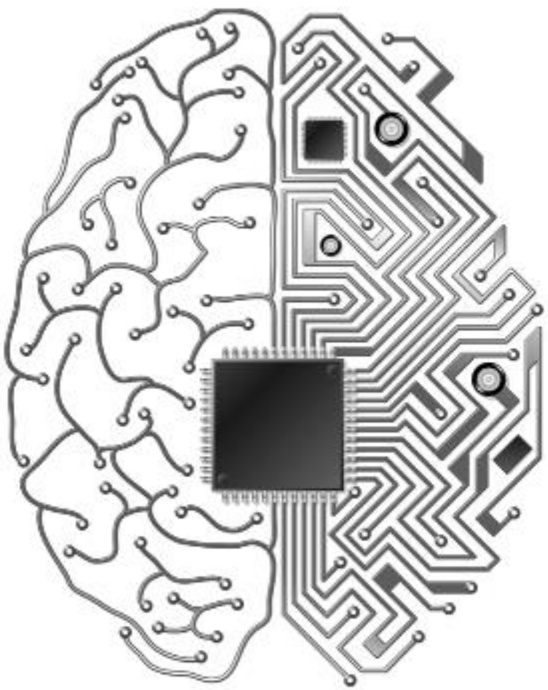
DISCUSSION

1. connectivity

2. dynamics



HUMAN EMOTION RECOGNITION USING FUSED PHYSIOLOGICAL SIGNALS

Shaun Canavan
Assistant Professor of Computer Science and Engineering
University of South Florida

APPLICATIONS

PHYSIOLOGICAL SIGNALS

Table 1. Physiological signal types from BP4D+*.

Signal	**Type**	**Measurement**
Blood pressure	Diastolic Systolic Mean (dia/sys) Raw BP	[-25, 300 mmHG]
Respiration	Rate Volts	[0, 200 breaths/min]
Heart rate	Pulse rate	[30, 300 beats/min]
EDA	EDA	Micro Siemens

*Zhang et al., "Multimodal Spontaneous Emotion Corpus for Human Behavior Analysis," CVPR 2016.

PHYSIOLOGICAL SIGNALS

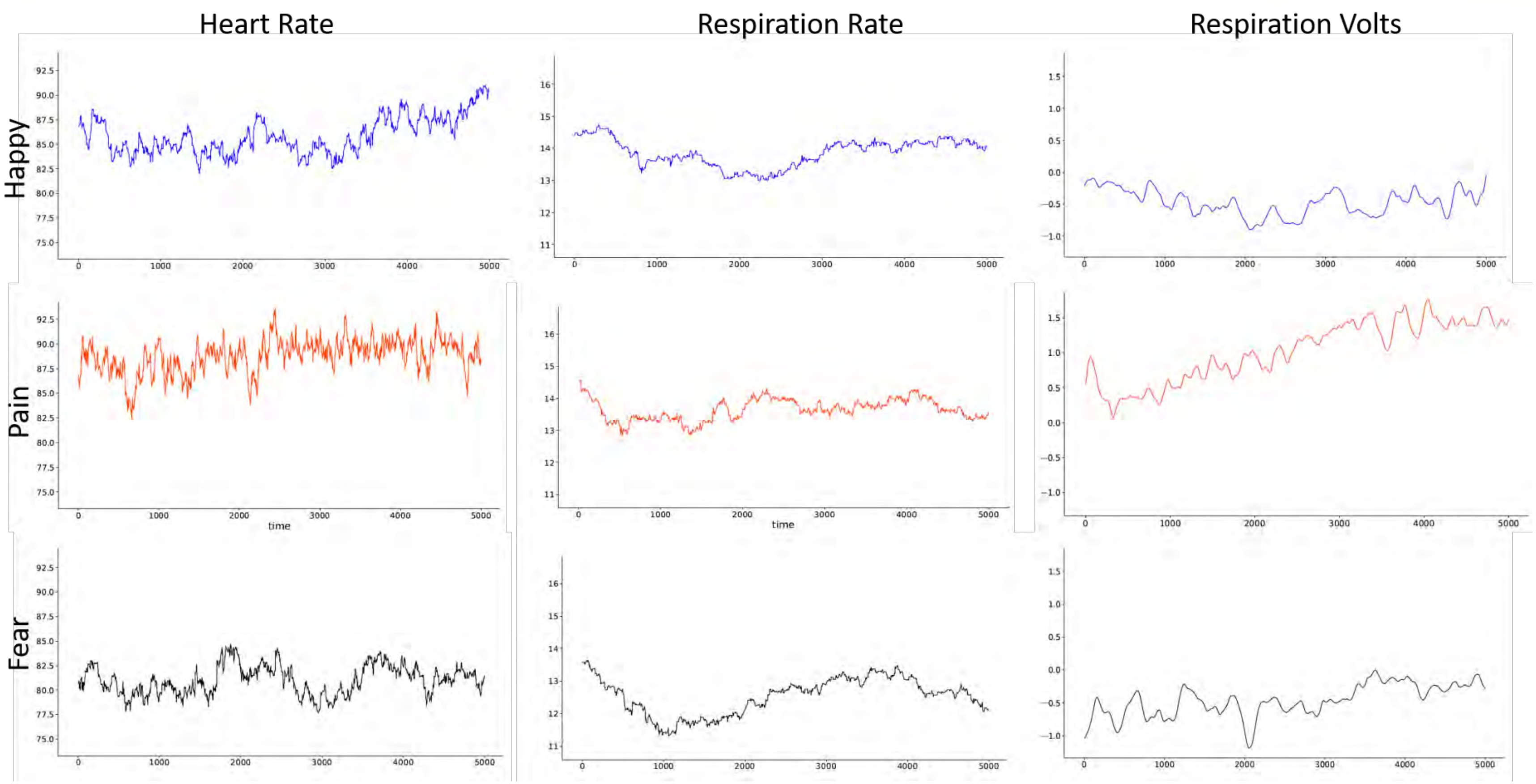
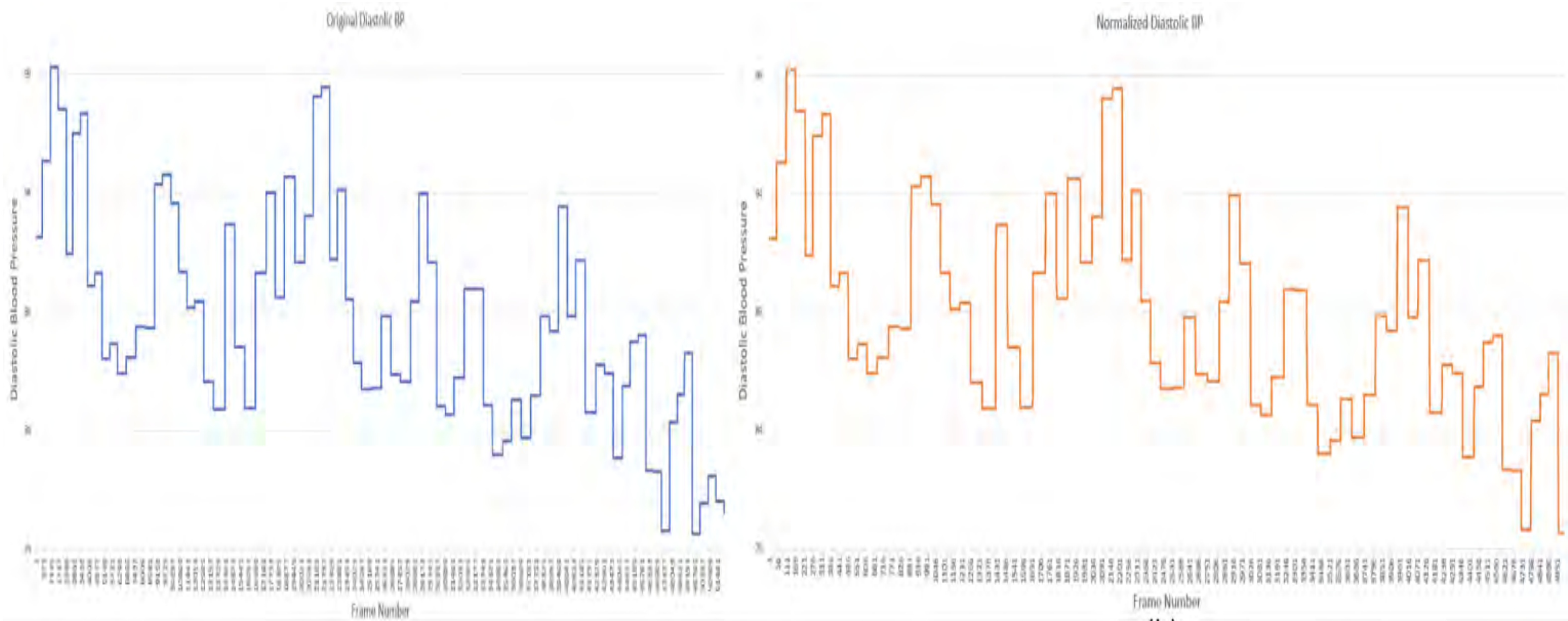


Figure 1. Comparison of signals for emotions of happy, pain, and fear.

FUSION OF PHYSIOLOGICAL SIGNALS



(a) (b)

Figure 2. Diastolic blood pressure of female subject.
(a) Original signal; (b) normalized signal.

FUSION OF PHYSIOLOGICAL SIGNALS

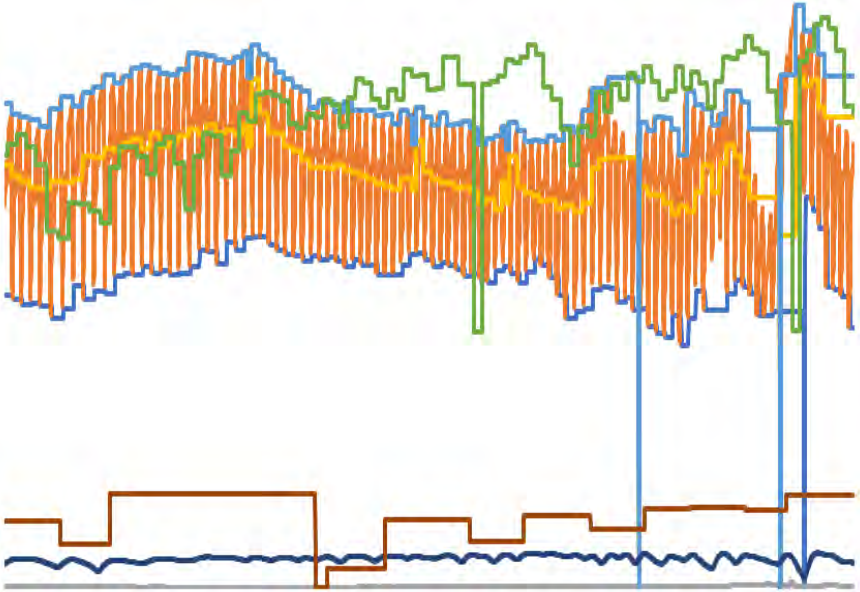


Figure 3. Physiological pain signals.

$$s^2 = \frac{\sum(x_i - \bar{x})^2}{n-1} \quad (1)$$

$$fused_{signal} = \sum_{i=1}^{N} (ns_i{}^2 \times FS_i) \quad (2)$$

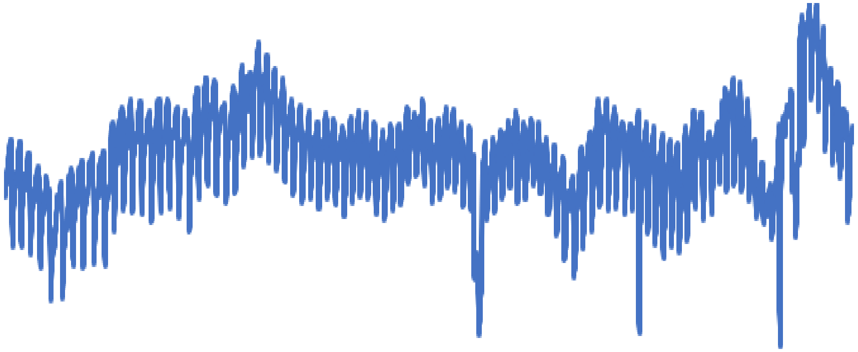


Figure 4. Fused pain signal.

EMOTION RECOGNITION WITH FUSED PHYSIOLOGICAL SIGNALS

Table 2. Recognition rates of 10 emotions.

Classifier	Accuracy
Support Vector Machine	**88.69%**
Naïve Bayes	86.87%
Random Forest	86.17%

Table 3. Recognition rates of pain vs. no pain.

Classifier	Accuracy
Support Vector Machine	**92.64%**
Random Forest	90.27%
Naïve Bayes	89.77%

Table 4. Prediction of 10 emotions.

Classifier	Accuracy
Random Forest	97.8%

EMOTION RECOGNITION WITH FUSED PHYSIOLOGICAL SIGNALS

Table 5. Recognition of 10 emotions with a deep feed-forward network.

Emotion	Fused Accuracy	Raw Accuracy (Exp 1)	Raw Accuracy (Exp 2)
Anger	**98.44%**	81.67%	84.05%
Happy	93.18%	71.96%	79.93%
Fear	92.70%	67.61%	79.84%
Embarrassment	92.08%	62.29%	84.19%
Startle	92.03%	74.85%	84.92%
Pain	91.37%	53.78%	84.23%
Sad	90.78%	49.09%	86.55%
Surprise	90.21%	63.42%	78.21%
Skeptical	90.00%	52.59%	79.93%
Disgust	85.14%	62.06%	75.72%
Average	**91.59%**	63.93%	81.16%

EMOTION RECOGNITION WITH FUSED PHYSIOLOGICAL SIGNALS

Table 6. Deep networks vs classical approaches for pain vs no pain.

Classifier	Accuracy
Deep Net Fused	**98.48%**
Deep Net Exp 1	97.14%
Deep Net Ext 2	95.36%
Support Vector Machine	92.64%
Random Forest	90.27%
Naïve Bayes	89.77%

BEYOND PHYSIOLOGICAL DATA

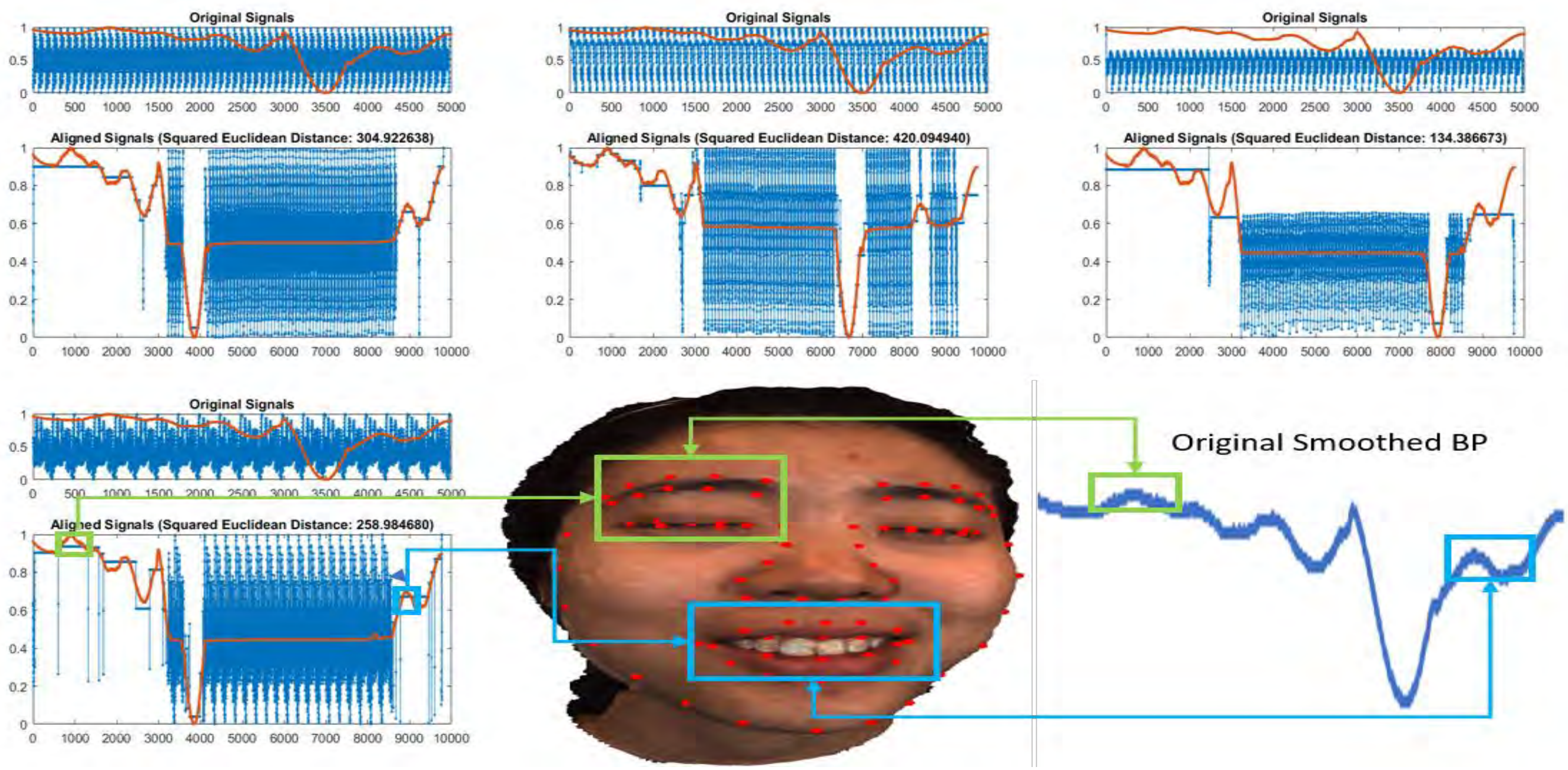


Figure 5. Inter-correlations between multiple modalities.

ACKNOWLEDGEMENTS

- Diego Fabiano
- Dr. Dmitry Goldgof
- Dr. Larry Hall
- Dr. Yicheng Tu
- Dr. Marvin Andujar

USF
UNIVERSITY OF
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NDIA Army Science and Technology Conference

EWA Government Systems, Inc.

Biologically-Inspired Processor for Ultra-Low Power Audio and Video Surveillance Applications

Presented by Lester Foster and Dirk Niggemeyer

Company EWA Government Systems Inc.

- Electronic Warfare Associates (EWA) Inc., was founded in 1977 to perform electronic warfare assessments for the US Government and transformed into a subsidiary EWA Government Systems Inc. in 2002.
- Our semiconductor development technology was developed in response to the challenge described in the **Army SBIR topic no. A12-106, entitled "Bio-Inspired Semiconductor Technology."**
- We have approximately 200 members on staff across multiple subsidiaries and joint ventures.
  - Small Veteran-Owned Business (SVOB)
- EWA CEO and Founder: Carl Guerreri
- EWA GSI Subsidiary President: Brian Moore
- EWA and EWA GSI Chief Technology Officer: Lester Foster, Ph.D.
- EWA Principal Engineer: Dirk Niggemeyer, Dr.-Engr.

Problem/Opportunity

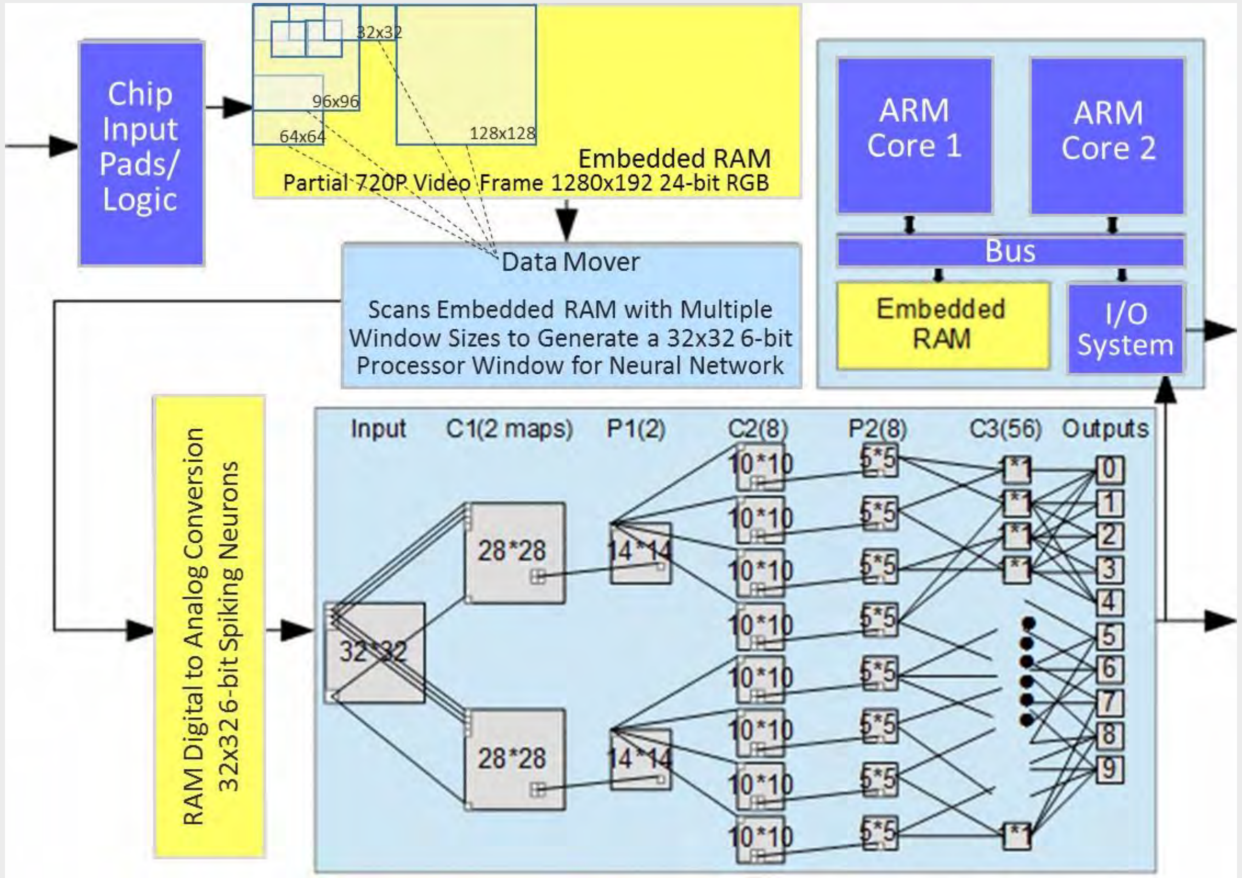
- Audio and video pattern recognition for surveillance applications
  - Classify sensor output to known patterns to identify content of interest.
  - Autonomous target classification and identification.
  - Useful with defense, security and law enforcement applications.
- Neural Network solutions successfully demonstrated pattern recognition
  - Employ processes similar to mammalian brain activities.
  - Implementation in software on standard processors requires substantial memory and power (“Brute Force” processing).
  - Excessive processor power required (10s of watts); not battery friendly.
  - Excessive training data required before networks can be deployed.
- Current processor technology utilizes transistors & Boolean binary logic
  - Reached the end of Moore’s Law (IC performance doubling every 18 months).
  - New approaches are required to increase computer processing performance.

➢ Opportunity for new processors based upon neural networks

Technology

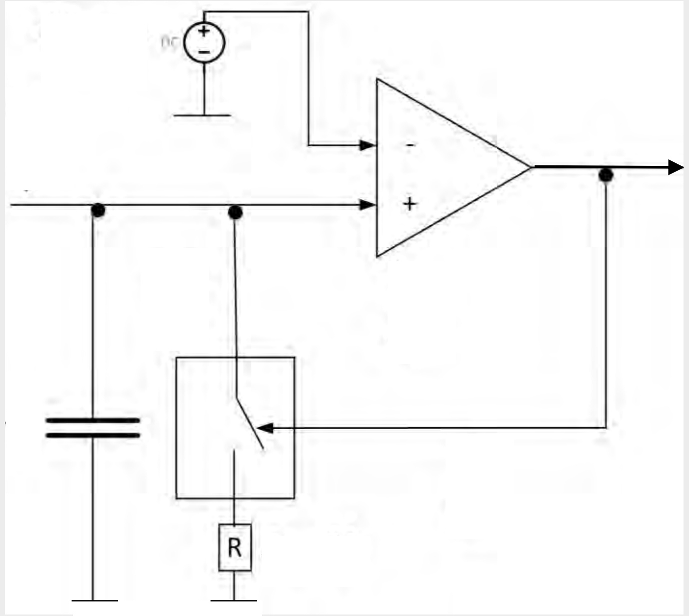
Compact Artificial Neural Network (ANN) Integrated Circuit Processor Core

- Compact ANN topology capable of 2-D circuitry layout employing a 32x32 pixel processing tile
  - Processing tiles scan across entire image for image recognition.
  - Larger tiles can be downscaled into processing tile during image scanning.
  - Processing tiles scan audio spectral plots of overlapping short time increments.
- Memristors, a new electronic device, are used to program processor to correlate patterns.
- Integrated with conventional processors, e.g., ARM cores, for hybrid multicore processing.
- **Potential to turn dumb cameras and audio collection sensors into smart low-power sensors.**



Architecture of the ANN Processor as a separate core with video input pre-processor of a multi-core processor

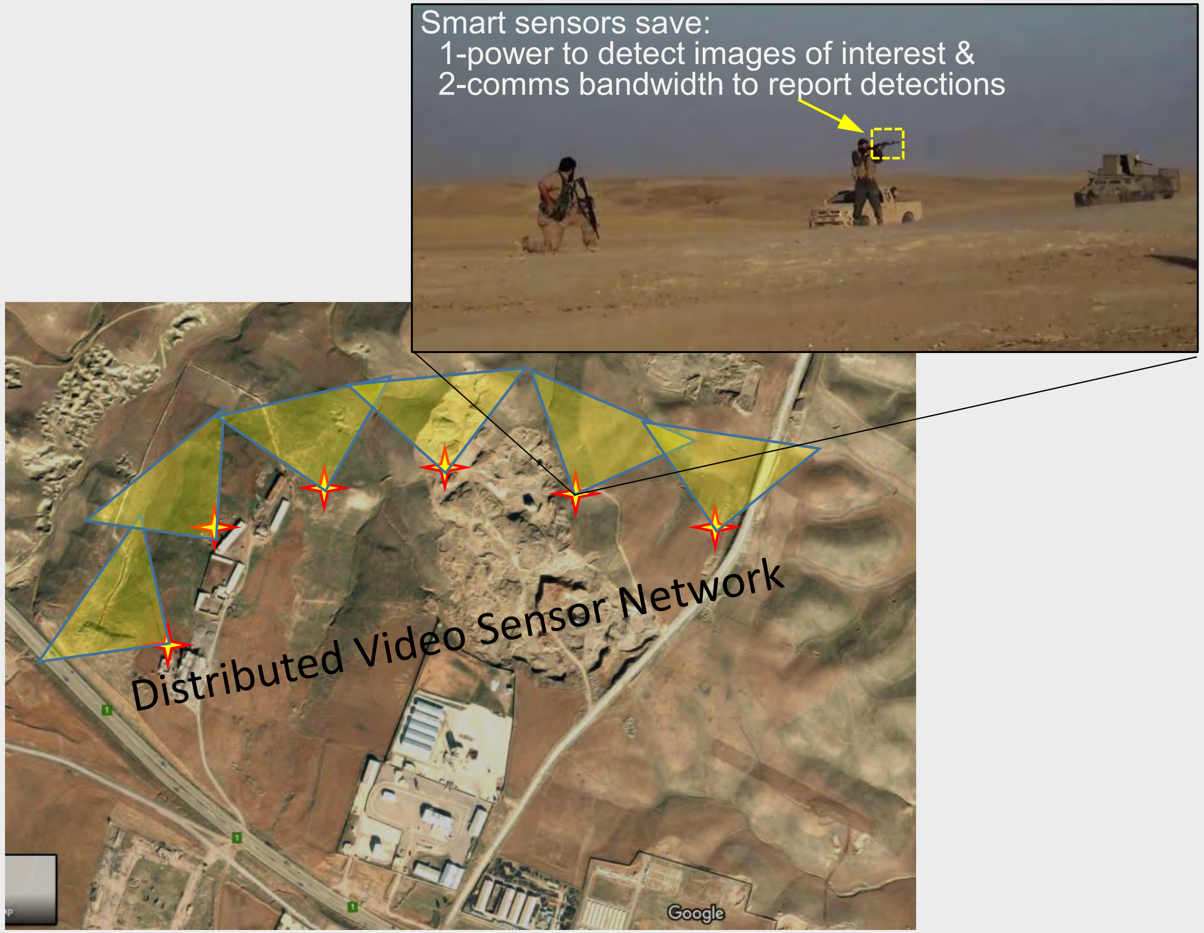
Key is Spiking Neuron



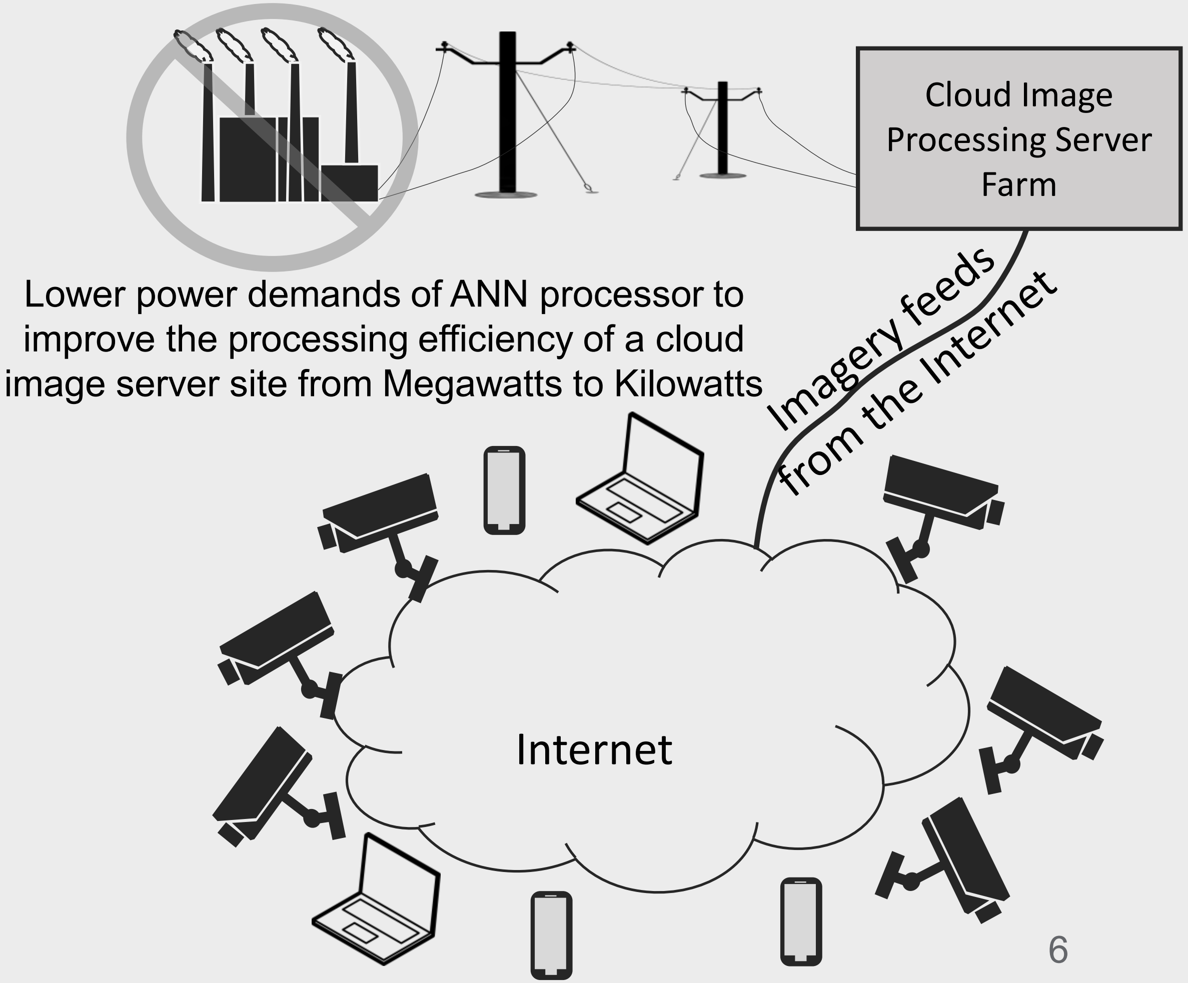
- Spiking neuron transmits information across neural network similarly to mammalian brain
  - Upstream currents and pulses build charge and voltage on capacitor until threshold voltage is reached on transistor.
  - Transistor fires short pulse which also flips switch to dump capacitive voltage to ground and resets the neuron.
  - Higher frequency spiking rate implies brighter pixel in image processing on input layer.
- Convolutions in digital logic reduce to additions of spikes
  - Replacing convolutions with weighted additions drastically reduces the power consumption of the neural network.
- Energy within each spike is very small: femtojoules (10^{-15})
- We have patented the conversion of digital data into spiking analog signals for spiking neural processing
  - We are now optimizing the digital logic, e.g., data mover, to further reduce power consumption of the overall system.

Concepts for Use

Smart Video Sensor Networking Applications



Intelligence and Law Enforcement Applications



Results to Date

- Revolutionary ANN processor design
  - Two patents to cover unique features of design.
- Ultra low power pattern recognition processing
  - Image processing only requires tens of milliwatts to process imagery for objects of interest.
  - Most power is consumed in the input digital data conversion to analog spiking signals of neural processing.
  - Minimal power processing through network.
- Software application to train or "program" pattern recognition into ANN processor core
- Convert dumb sensors to smart sensors
  - Image processing at camera source eliminates imagery data overloads on networks.
  - Processing power negligible compared to sensor.
  - Lower comms bandwidth to relay only interesting data.
- Processor can be integrated in any platform from smartphones to video and audio collection processing servers

EWA Government Systems, Inc.
Enabling a more secure future

Images used to train the ANN to recognize AK-47 Rifles from random pictures off the internet

Performance: Probability of Detection at 90%

Comparison to Conventional Processors

EWA Government Systems, Inc.
Enabling a more secure future

EWA GSI's ANN Processor Solution	High End Conventional Technology Approach
Artificial Neural Network (ANN) Processor programmed with training application	Conventional multi-core processor with operating system and state-of-the-art Yolo-2 pattern recognition application
Fast processing of imagery, 1 microsecond to process 32x32 pixel image tile	Real-time processing requires significant processing power
Spiking neurons and network synapses	Neural network coded with conventional software
<33 milliwatts to process 720P HDMI video at 60 frames per second	10s of watts to process 720P HDMI video at 60 frames per second
Demonstrated 90% probability of detection for targeted items	Probability of detection was estimated at 78%

ANN Development Team

- ANN Processor Core Development Team Key Players:
  - Program Manager and Chief Technology Officer: Lester Foster PhD (EWA GSI)
  - Principal Investigator and Principal Engineer: Dirk Niggemeyer, Dr.-Engr. (EWA GSI)
  - ANN Consultant and President: Elizabeth Rudnick PhD (Imaginic, Inc.)
  - Memristor Research Lead and Associate Professor: Nathaniel Cady PhD (University of Albany, SUNY)
- Our team is sufficient & complete to develop the revolutionary ANN processor to TRL 6

Contact

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    Herndon, VA 20171
  - (703) 904-5087 (o), (703) 789-3263 (m)
  - lfoster@ewa.com
  - www.ewa-gsi.com
    www.ewa.com

Implementing Emotions in Cognitive Robots

Lyle N. Long
Aerospace Engineering, Mathematics, and Computational Science
The Pennsylvania State University

Troy D. Kelley
U.S. Army Research Lab
Aberdeen, Maryland

Introduction

- Emotions and temperament help animals (including humans) survive
- Emotions are important memory triggers. Emotional events are remembered well
- Robots that vary their behavior based on their emotions should be more effective
- Although not addressed here, robots with emotions and temperament might be better at interacting with humans also

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Emotions vs. Temperament

ARL

- <u>Emotions</u> vary with time due to reward and punishment
- <u>Temperament</u> (personality) is essentially fixed, but can vary across individuals
- The model presented herein couples <u>emotions</u> and <u>temperament</u> together into a cognitive architecture on a mobile robot using the Symbolic and Sub-symbolic Robotics Intelligence Control System (SS-RICS)

Emotions Used in Simulations

- ❑ Fear
- ❑ Anger
- ❑ Sadness
- ❑ Happiness
- ❑ Disgust
- ❑ Surprise

- All those shown in Plutchik color wheel
- Each can vary from 0 to 100
- Largest chosen (winner take all)

(could also model Trust, and others)

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Model Created for Emotions

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$$Emotion(t)_i = w_{o_i} + \sum_{j=1}^{t} \gamma_i^{(t-j)} \left(w_{1_i} R_{ij}^{+} + w_{2_i} R_{ij}^{-} \right)$$

Eight emotions that vary with time

Fixed coefficients that define temperament

Rewards & Punishments

(Inspired by: Rutledge et al, PNAS 2014)

Note: There are similarities between cognitive models of memory and the above equation

Five main types of temperament in humans and other animals

Often called the Big Five Temperaments (Digman, 1990):

- Extrovert vs. Introvert
- Neurotic vs. Rational
- Conscientious vs. Careless
- Agreeable vs. Disagreeable
- Open vs. Reticent

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Define a Temperament Matrix

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Fixed array of constants to define robot's personality, from emotion equations

$$T_{ij} = \begin{bmatrix} w_{0_1} & w_{1_1} & w_{2_1} & \gamma_1 \\ w_{0_2} & w_{1_2} & w_{2_2} & \gamma_2 \\ w_{0_3} & w_{1_3} & w_{2_3} & \gamma_3 \\ w_{0_4} & w_{1_4} & w_{2_4} & \gamma_4 \\ w_{0_5} & w_{1_5} & w_{2_5} & \gamma_5 \\ w_{0_6} & w_{1_6} & w_{2_6} & \gamma_6 \end{bmatrix} \begin{array}{l} \text{Fear} \\ \text{Anger} \\ \text{Sadness} \\ \text{Happiness} \\ \text{Disgust} \\ \text{Surprise} \end{array}$$

Steady state value

Reward factor

Punishment factor

Decay rate

Example Temperament Matrix

$$T_{ij} = \left[\begin{matrix} 50 & 0.52 & 0.35 & 0.72 \\ 75 & 0.52 & 0.35 & 0.72 \\ 50 & 0.52 & 0.35 & 0.72 \\ 50 & 0.52 & 0.35 & 0.40 \\ 50 & 0.52 & 0.35 & 0.72 \\ 60 & 0.70 & 0.35 & 0.72 \end{matrix}\right] \begin{matrix} \text{Fear} \\ \text{Anger} \\ \text{Sadness} \\ \text{Happiness} \\ \text{Disgust} \\ \text{Surprise} \end{matrix}$$

Steady state value

Reward factor

Punishment factor

Decay rate

These values, so far, have been chosen to be near the values in Rutledge et al, PNAS 2014.
More work needs to be done in tuning tehse parameters.

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Cognitive Architecture Used

ARL

- Symbolic and Sub-symbolic Robotic Intelligence Control System (SS-RICS)
- Developed at US Army Research Lab, Aberdeen, MD (Troy Kelley, Eric Avery, Sean McGhee, and others)
- Inspired by ACT-R (Carnegie Mellon)
- Lots of libraries for navigation, mapping, visual processing, sensors, and motor control
- Laser range finder, mono camera, stereo camera, wheel encoders, sonar sensors, stereo microphones, stereo speakers, …
- Written mainly in C#

- Works with variety of robots (Mobile Robots Pioneer robots, the SRV-1 robot, the iRobot PackBot, and Clearpath's Husky A200)
- Easily moved to new ones

SS-RICS with Emotion & Temperament

- The Emotion Engine is a sub-symbolic process (unconscious) within SS-RICS
- Written in C++
- Robot is given a temperament matrix to use (personality)
- As robot roams around SS-RICS sends rewards or punishment info to the emotion engine
- The emotion engine keeps track of these and uses the equations shown earlier to predict a numerical value of all emotions as functions of time
- Emotion engine sends current values of emotions (and info on largest one) back to SS-RICS
- Emotions are essentially state variables, so Productions can include info on emotions

Results

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SS-RICS Simulation Results

ARL

- Simulator is given map of the building with objects that spur emotions distributed around map
- It roams around the building searching for one object
- Robot speaks when it is near the objects ("I see danger"), and these objects can change its emotion
- Robot also periodically states what emotion it is "feeling" (e.g. "I feel happy")
- **Depending on emotion it is feeling, its behavior is modified** via SS-RICS productions

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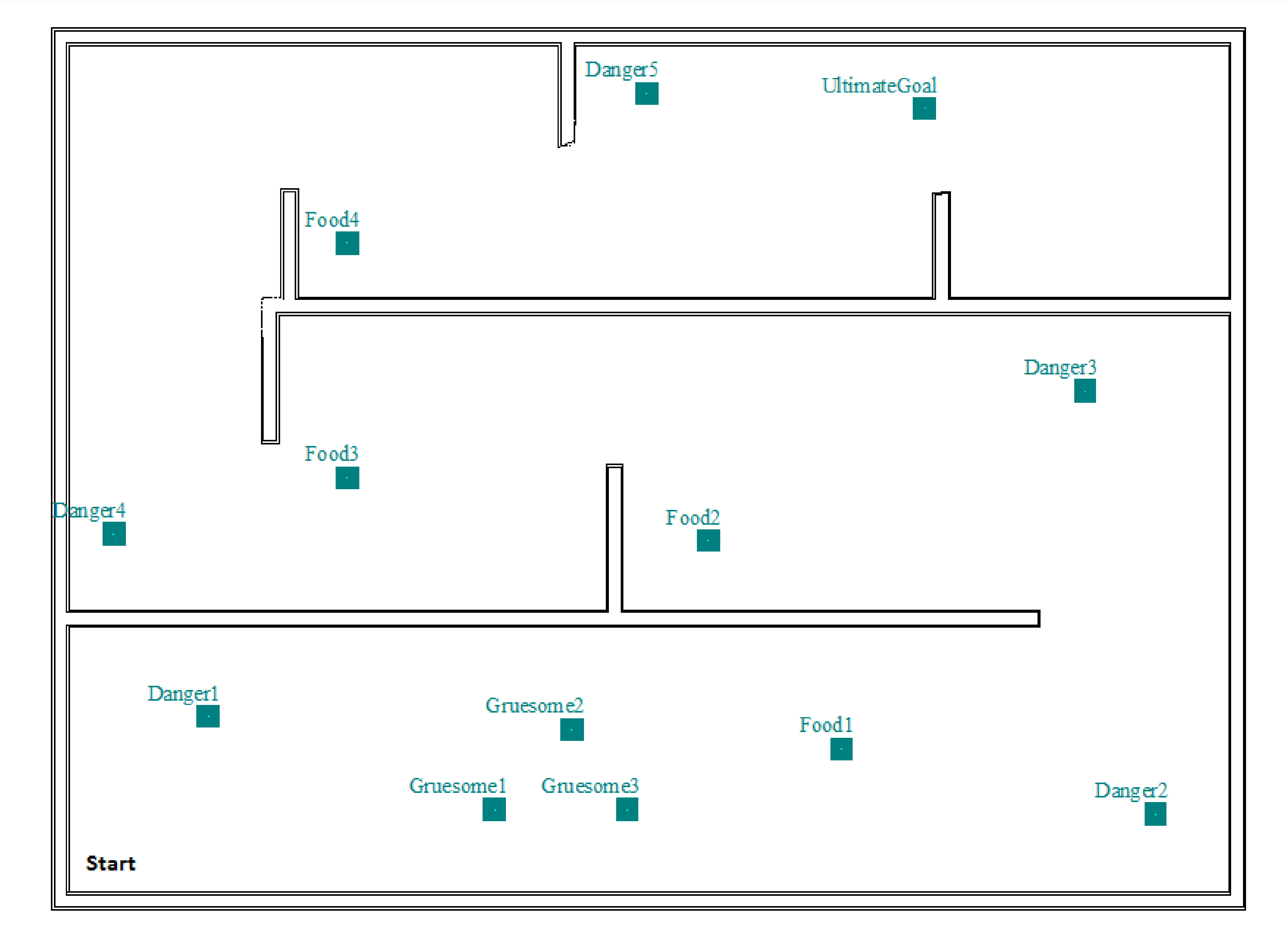
Map Used for Tests

ARL



for Land Forces

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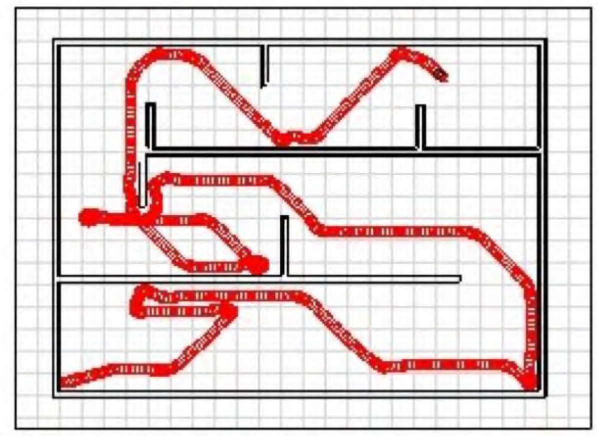
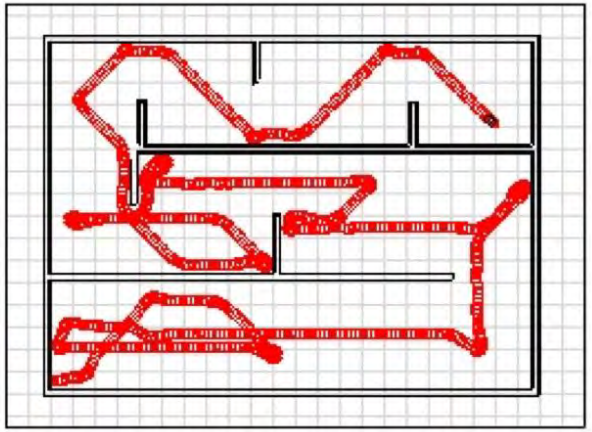
Routes Taken by Robots

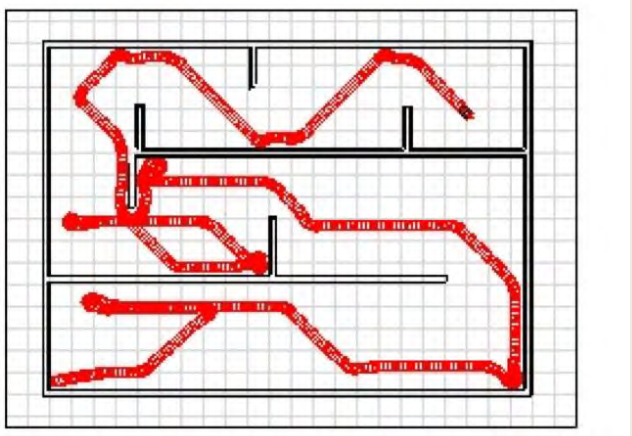
ARL



Angry



Happy



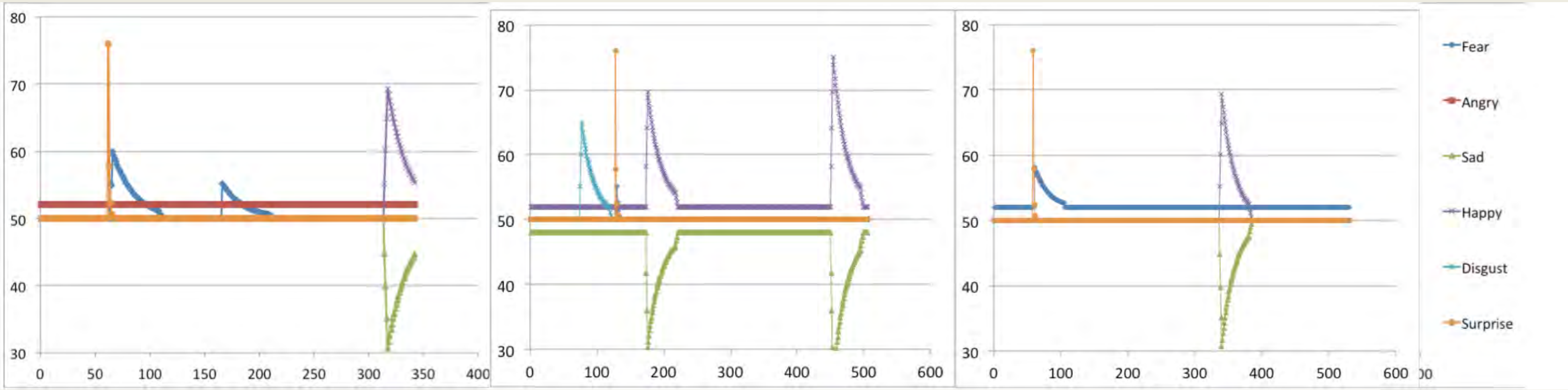
Fearful

Robots travel thru maze and experience items that effect their emotions. All robots go thru same maze and experience same items. Robots with different temperaments behave differently.

Emotion Time Histories

Angry Happy Fearful

Emotion Values



Time Time Time

Robots travel thru maze and experience items that effect their emotions. Robots with different temperaments have different emotion time histories.

Robot Test Cases

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Robot Results

ARL

- Ran the same tests as ran in simulator but on mobile robot (results were essentially the same qualitatively)
- Objects were stored in map
- Robot speaks when it sees these things ("I see danger")
- Robot also periodically states what emotion it is "feeling" (e.g. "I feel happy", "I'm afraid", "I'm very afraid")
- Depending on emotion it is feeling, its behavior is modified
- It roams around the building looking for a particular object while it builds a map of the building

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Conclusions

ARL

- Emotion and temperament model has been developed
- It has been incorporated into a cognitive mobile robot
- Will run more extensive tests in future
- Will also work to evaluate the emotion/temperament model and the temperament matrix
- It would also be interesting to couple memories and storage. Emotions can influence memories.
- More Details in:

Long L.N., "A Model for Temperament and Emotions on Robots. In: Chen J. (eds), Advances in Human Factors in Robots and Unmanned Systems. AHFE 2017. Advances in Intelligent Systems and Computing, vol 595. Springer, 2018.

Thank You. Questions?

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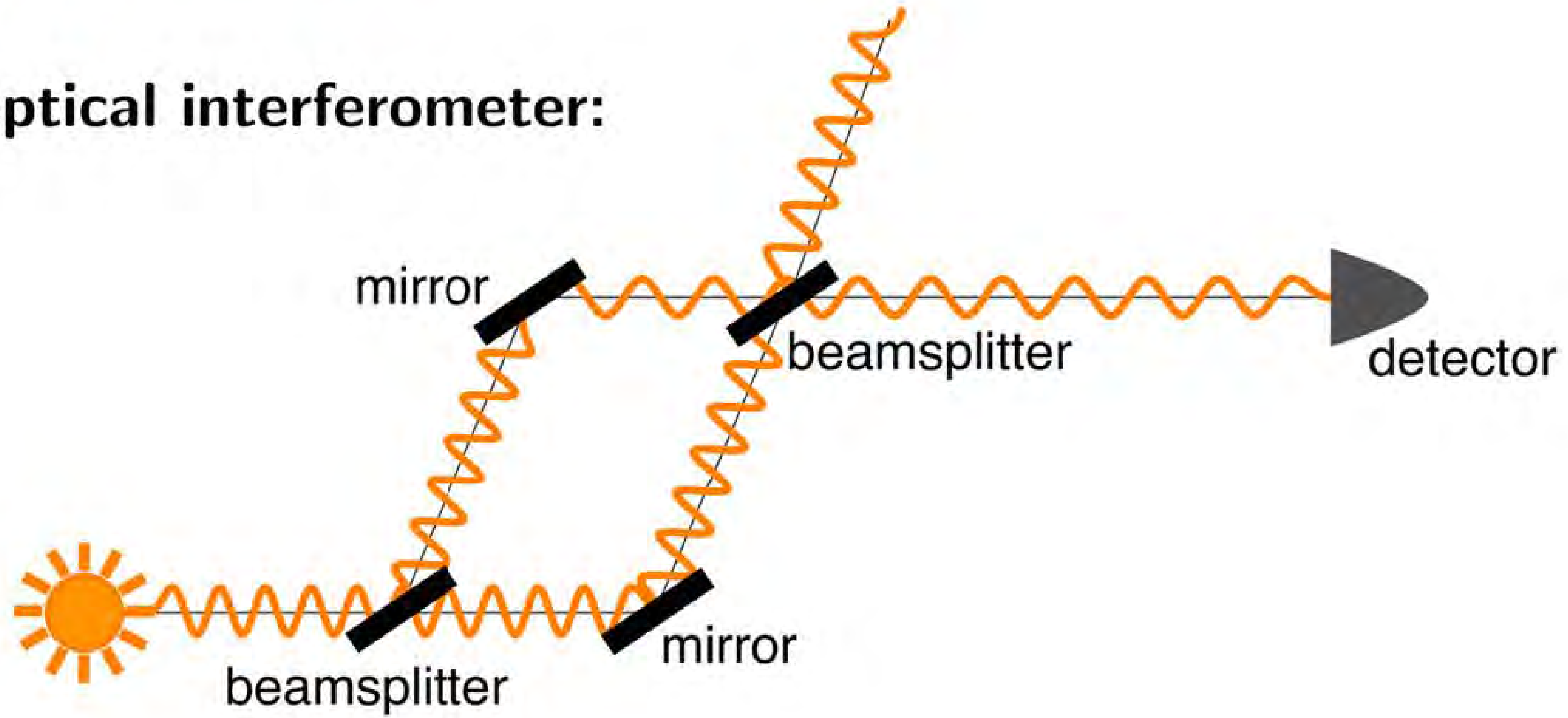
Optimal pulse schemes for high-precision atom interferometry

Michael Goerz[1], Paul Kunz[1], Mark Kasevich[2], Vladimir Malinovsky[1]

[1]U.S. Army Research Lab, [2]Stanford University

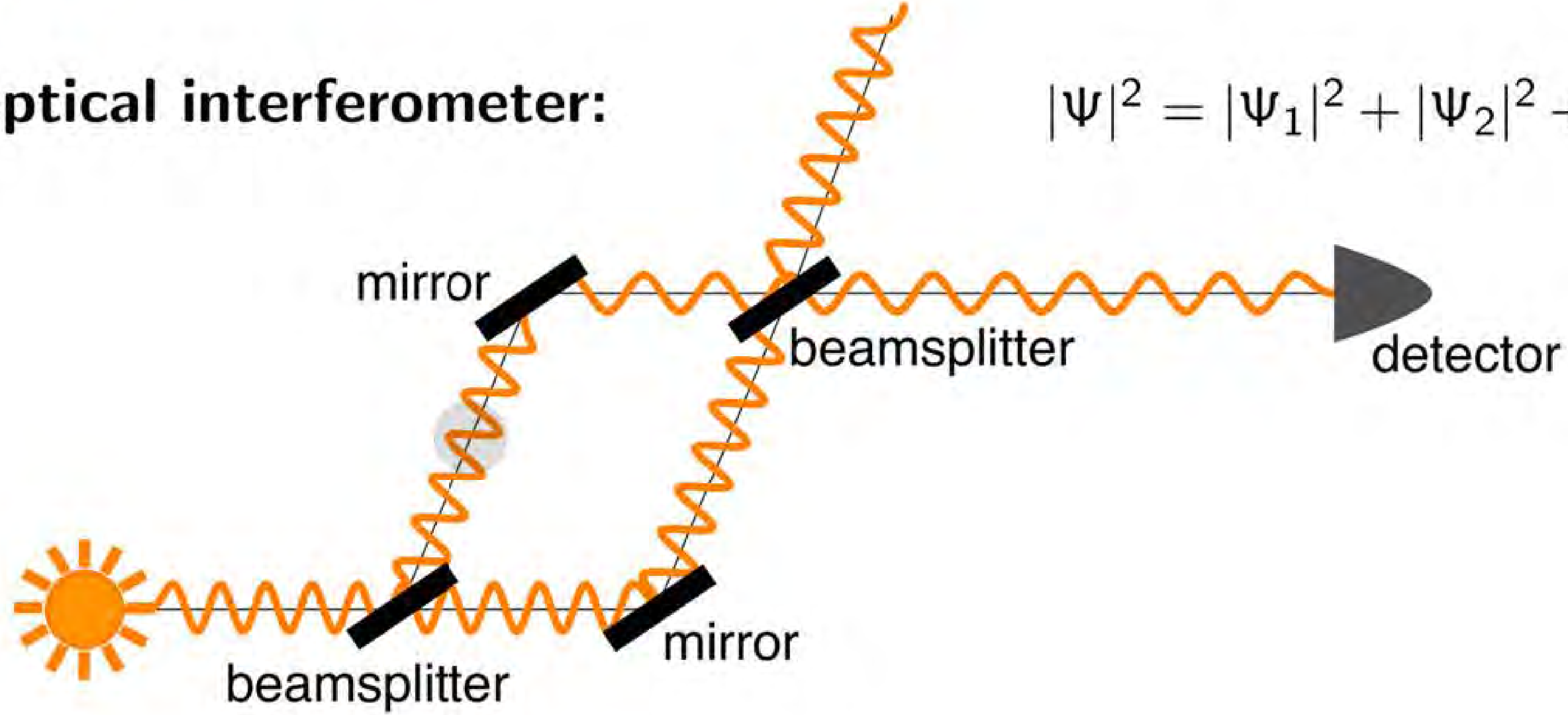
23 August 2018

optical interferometer:



optical interferometer:

$$|\Psi|^2 = |\Psi_1|^2 + |\Psi_2|^2 + 2\Psi_1\Psi_2\cos(\phi_1 - \phi_2)$$



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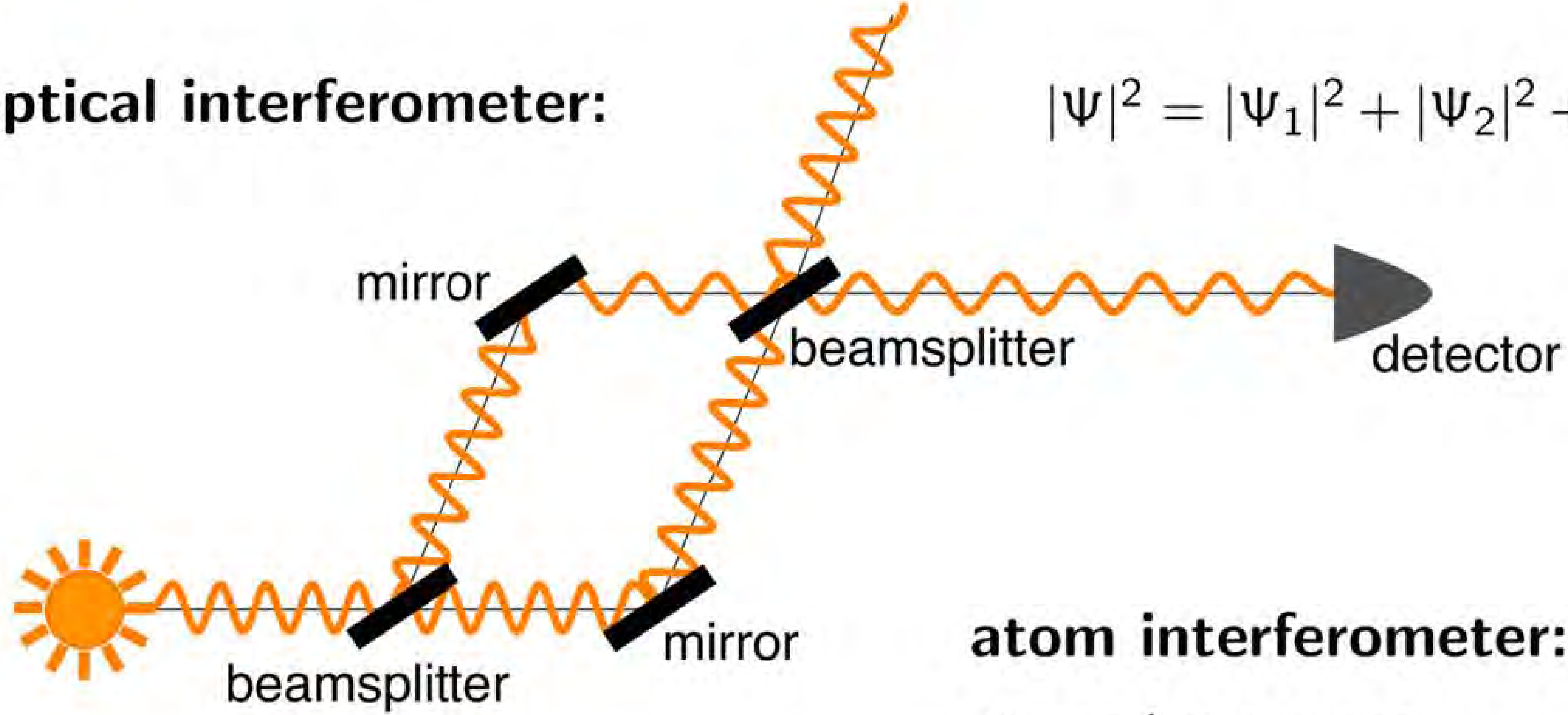

atom interferometer:

atoms have *mass*
and *internal structure*
$\Rightarrow$ couple to more external perturbations (gravity)

optical interferometer:

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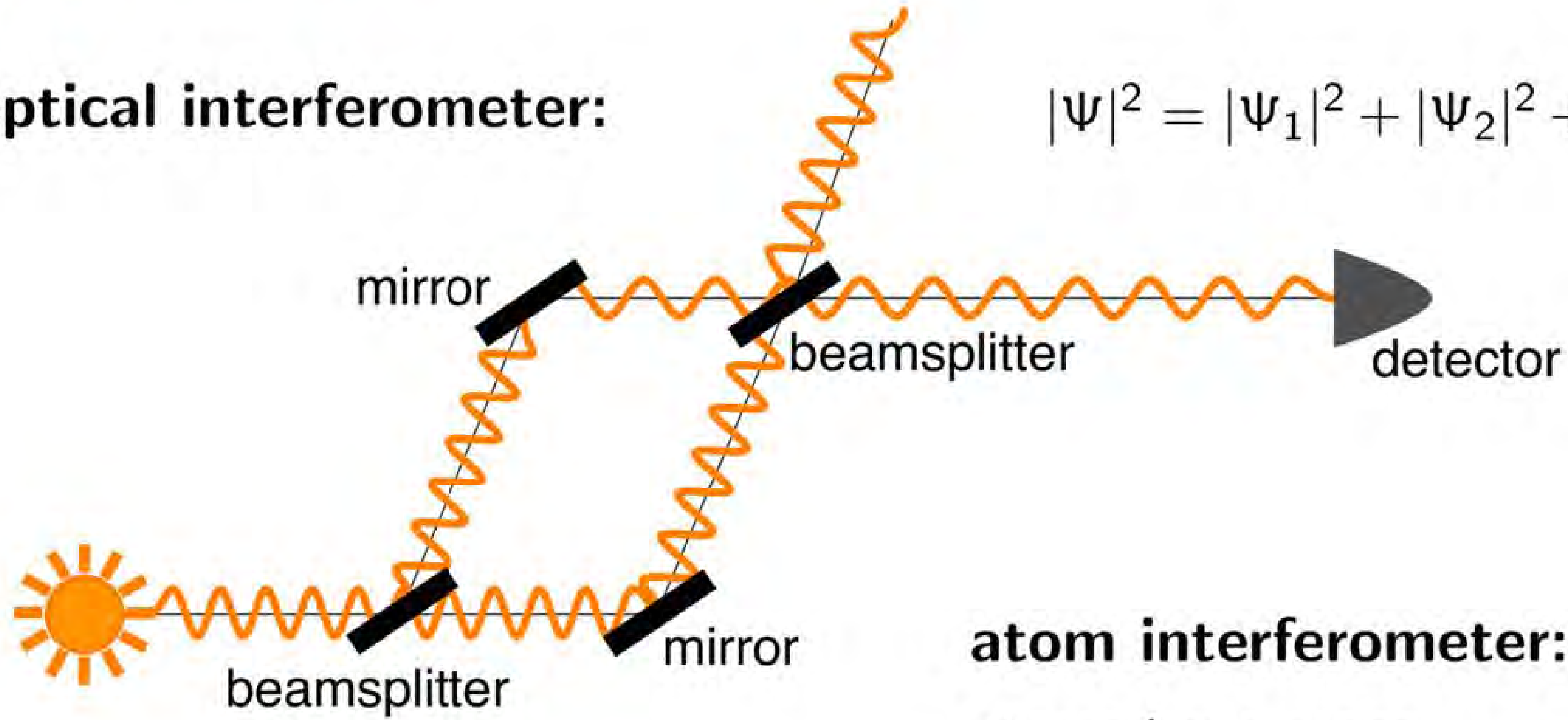
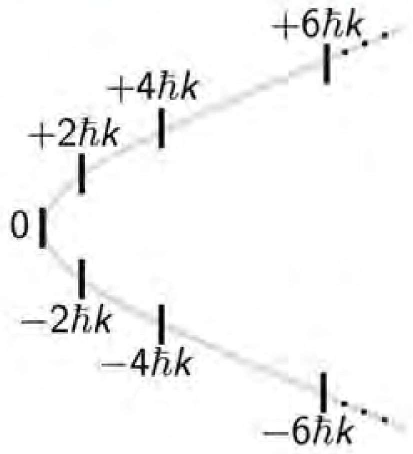


atom interferometer:

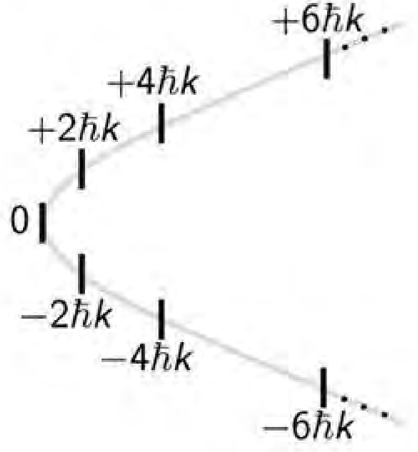
atoms have *mass*
and *internal structure*
$\Rightarrow$ couple to more external perturbations (gravity)

mirror? beamsplitter?



laser couples between electronic states: absorbs photon momentum

10 m atomic fountain at Stanford: ultracold ^{87}Rb atomic cloud



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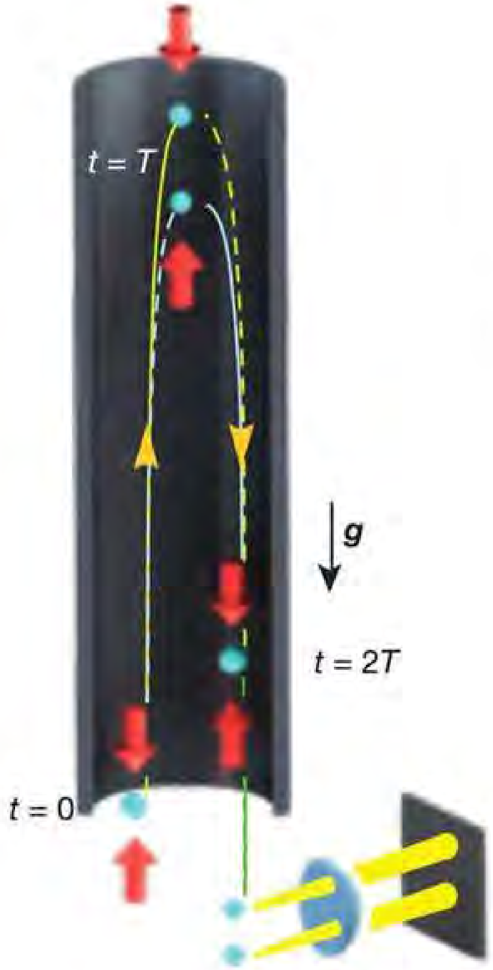
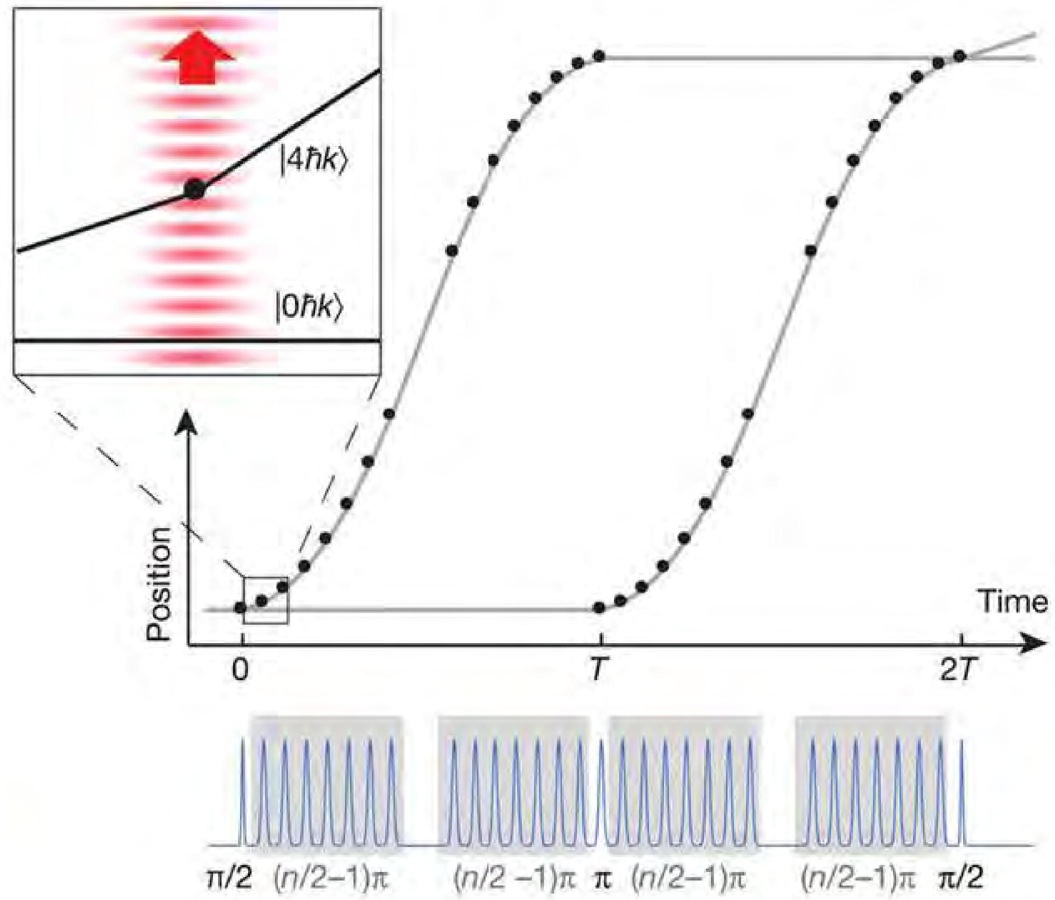
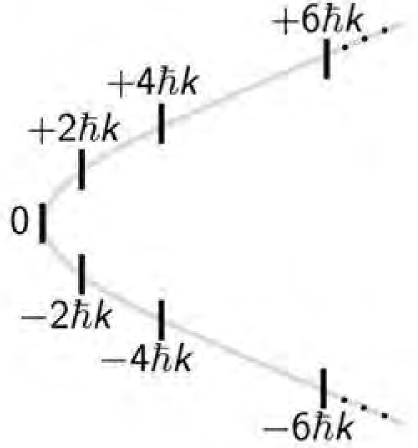




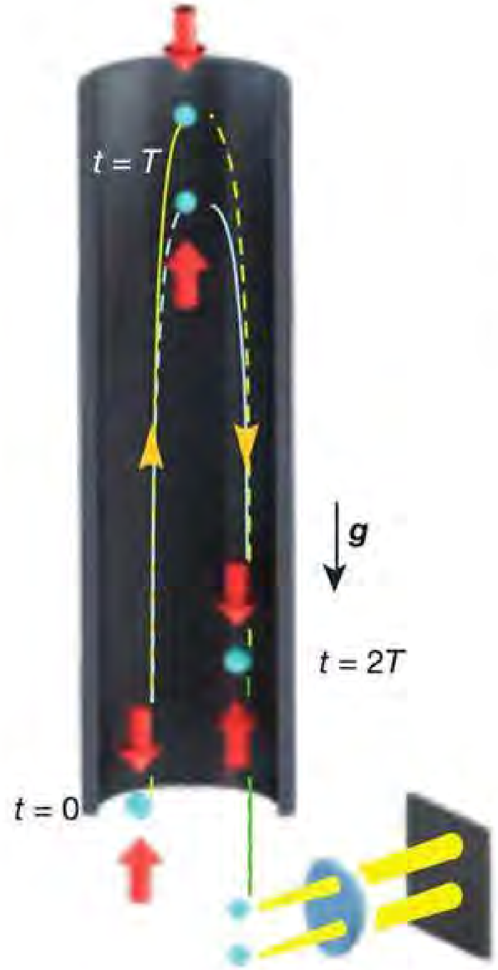
Kovachi et al. *Nature* **528**, 530 (2015)

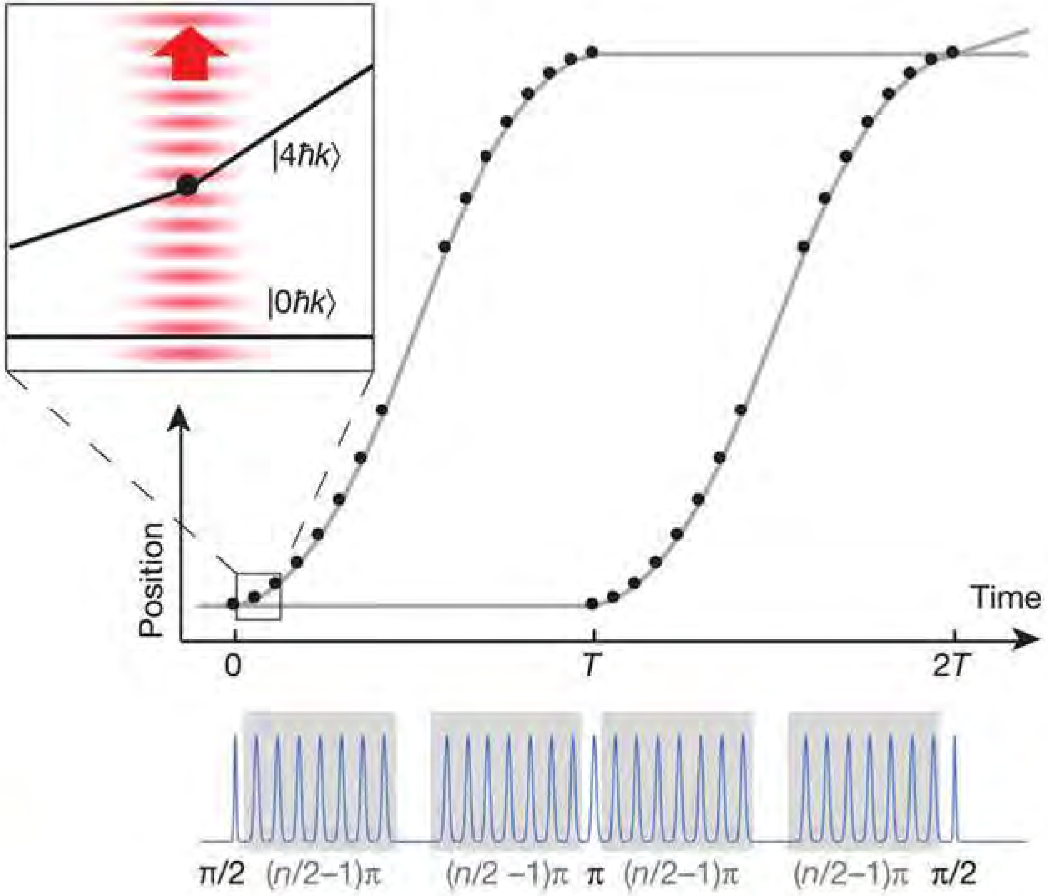
10 m atomic fountain at Stanford: ultracold ^{87}Rb atomic cloud



laser couples between electronic states: absorbs photon momentum

$$\Delta\phi = -2k_{\text{max}} g T^2$$



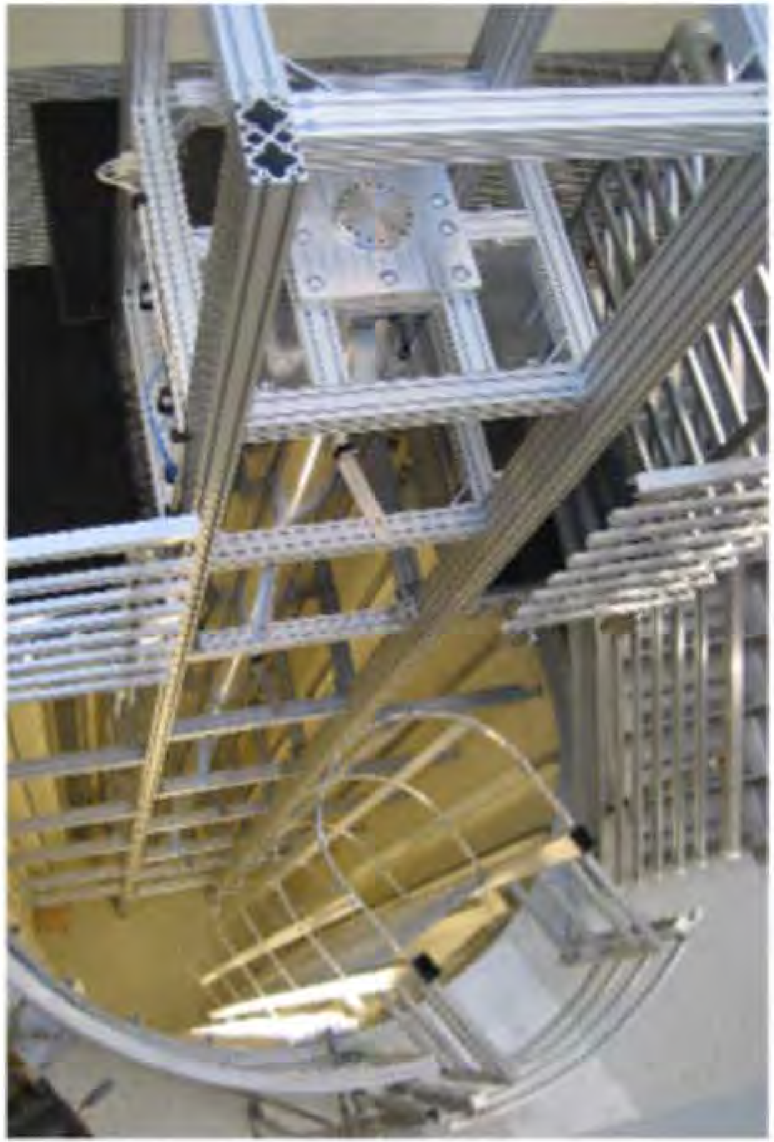


Kovachi et al. *Nature* **528**, 530 (2015)

Army applications:
ultra-precise measurement of acceleration / gravity

- inertial navigation: submarines, autonomous vehicles —not jammable!
  - gyroscopes
  - gravity gradient sensors
- weapons system control
- geospatial mapping
- drone or satellite based detection of underground structures

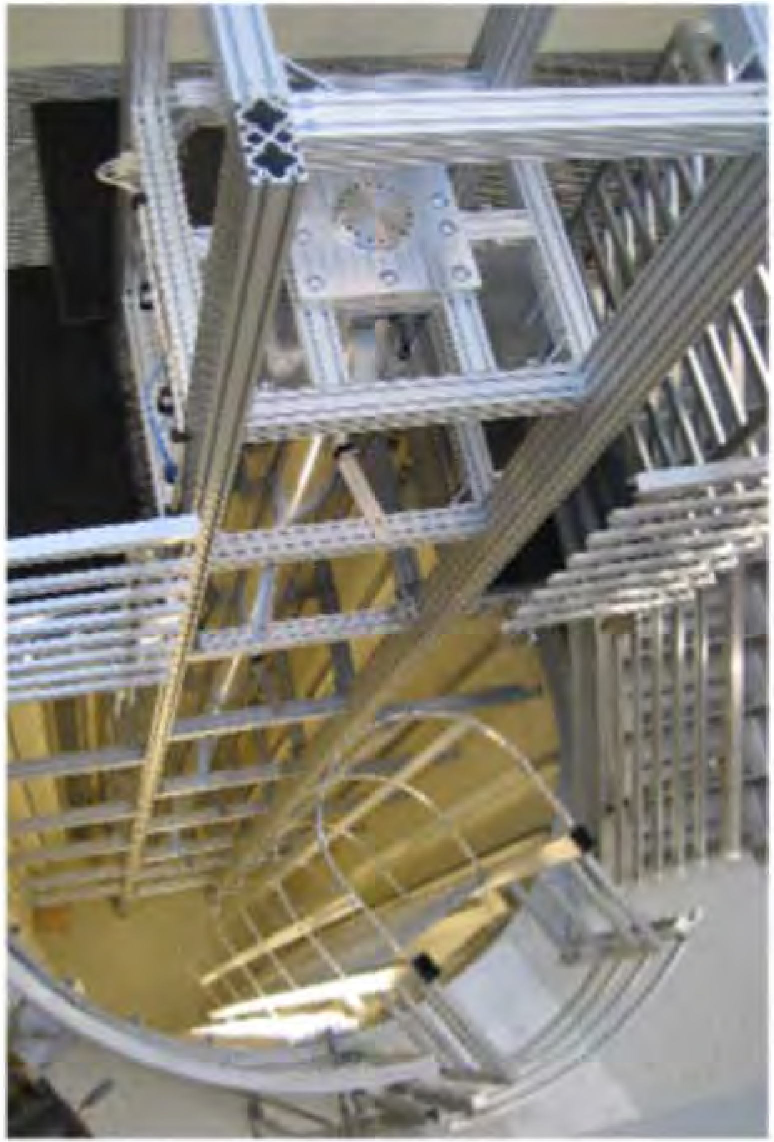
10 m atomic fountain: sensitivity 10^{-13} g/$\sqrt{\text{Hz}}$



?

AOSense (2010)
10^{-6} g/$\sqrt{\text{Hz}}$

state of the art
10^{-9} g/$\sqrt{\text{Hz}}$



10 m atomic fountain: sensitivity $10^{-13}\ \mathrm{g}/\sqrt{\mathrm{Hz}}$

factors:

- signal to noise ratio
- large momentum transfer

?

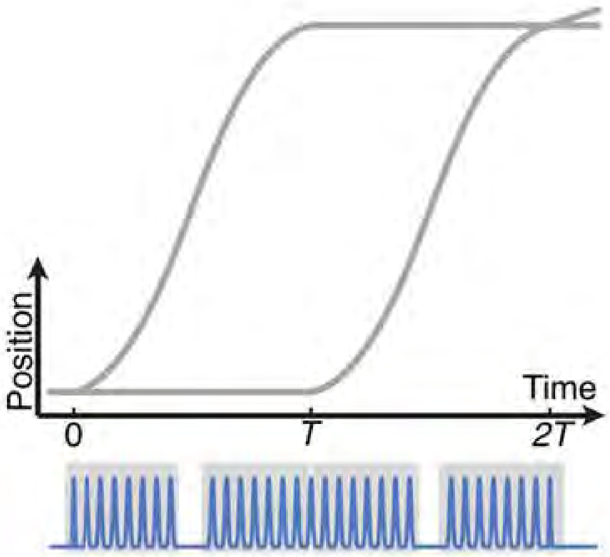
AOSense (2010)
$10^{-6}\ \mathrm{g}/\sqrt{\mathrm{Hz}}$

state of the art
$10^{-9}\ \mathrm{g}/\sqrt{\mathrm{Hz}}$

Apply optimal control to atom optics pulses

$\Rightarrow$ increase fidelity

$\Rightarrow$ robustness against fluctuations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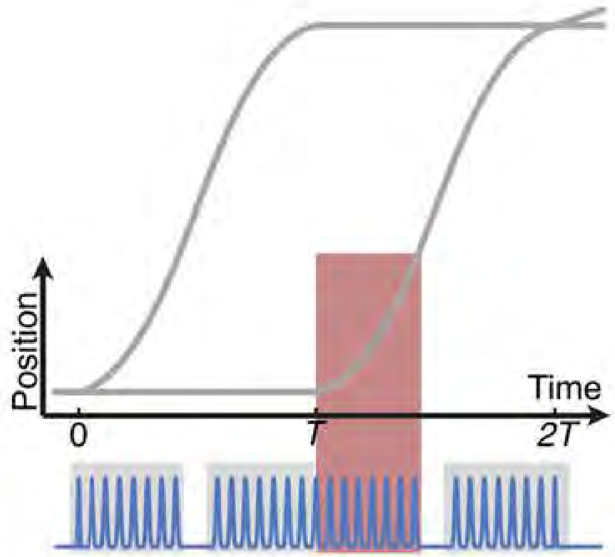
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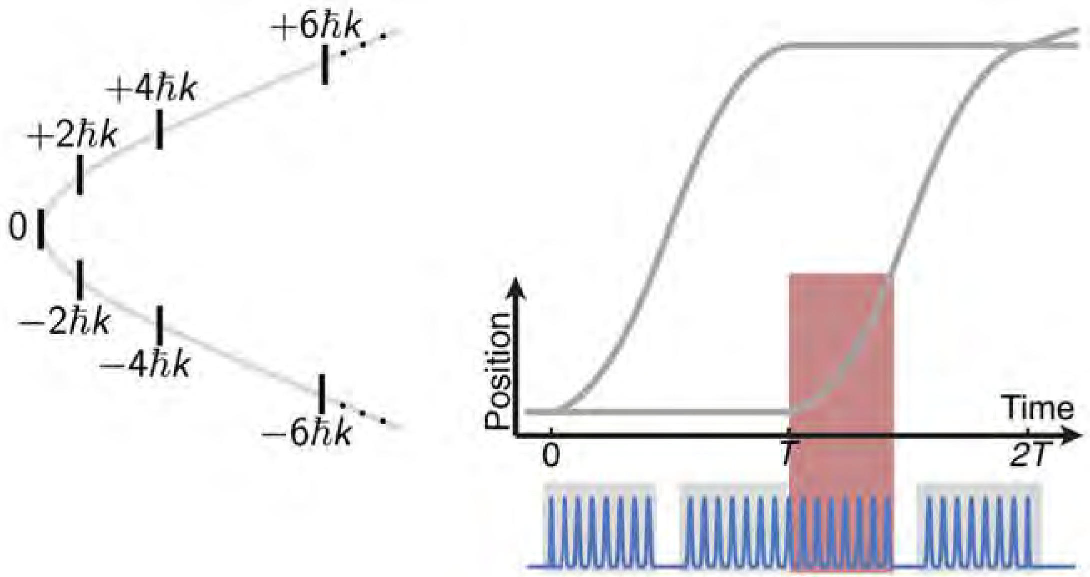
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$+4\hbar k$
$+2\hbar k$
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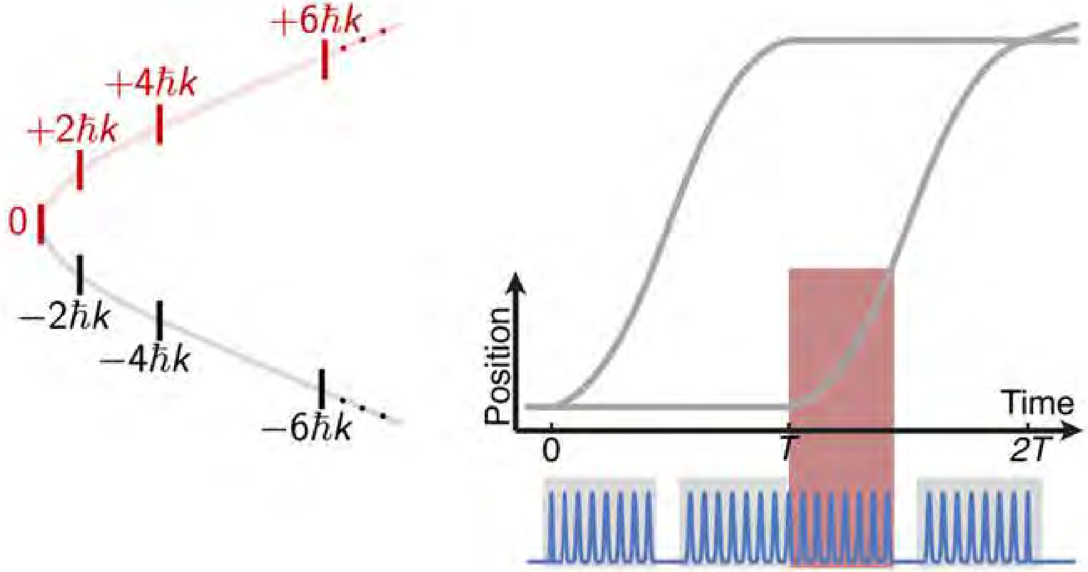
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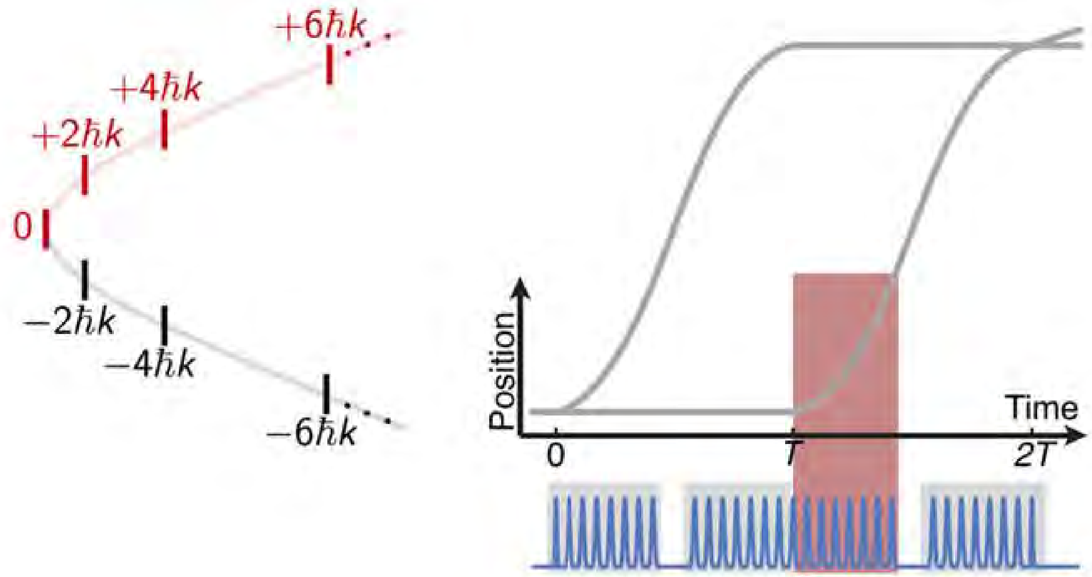
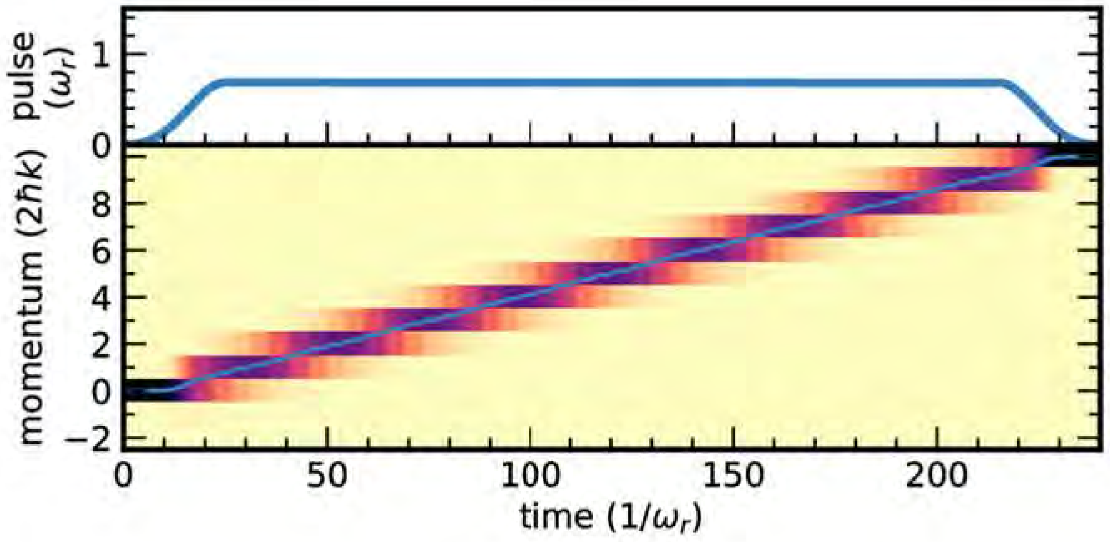
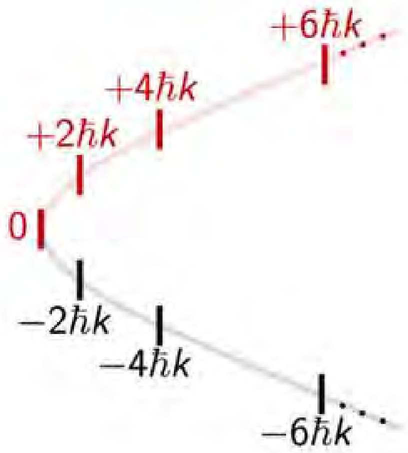
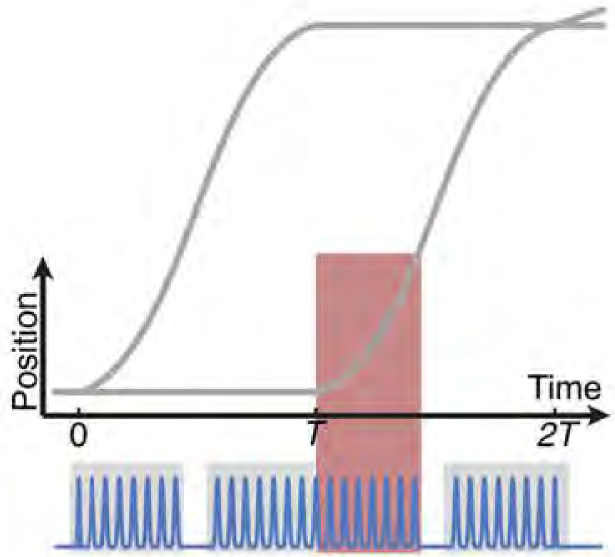


train of pulses $\Rightarrow$ rapid adiabatic passage:
tune through laser frequency at constant amplitude







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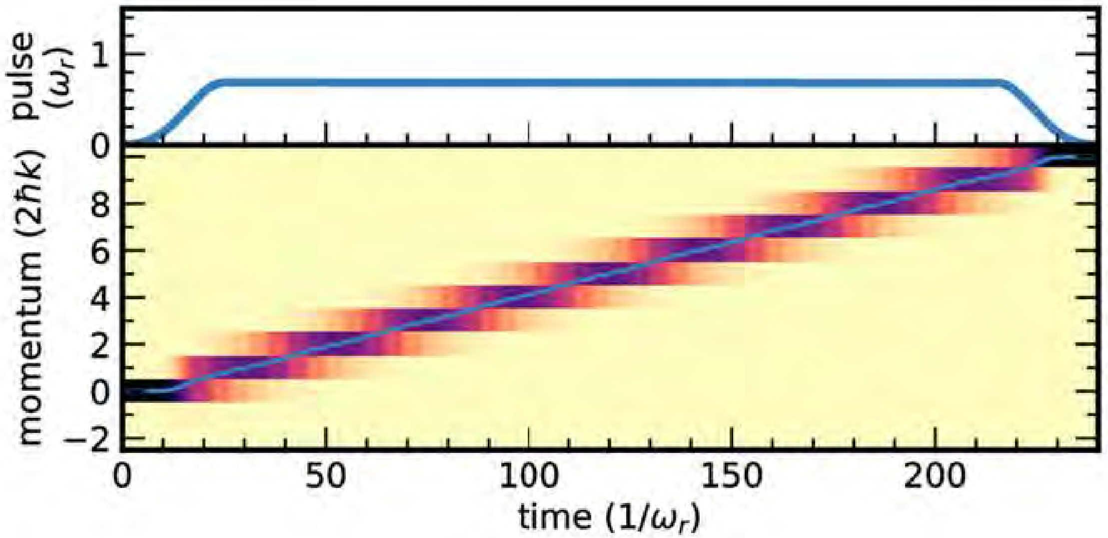
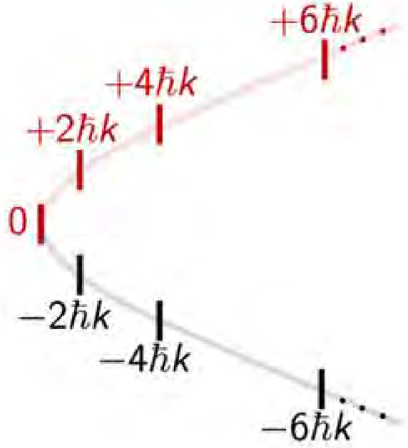

pulse (ω_r)
momentum ($2\hbar k$)
time ($1/\omega_r$)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$+4\hbar k$
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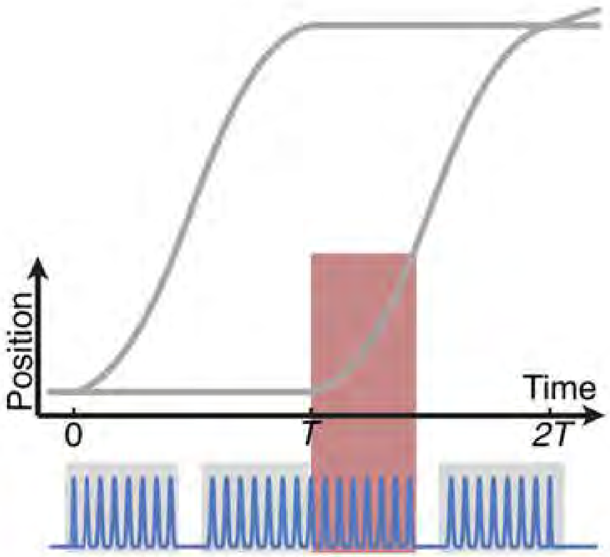
$-6\hbar k$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Time
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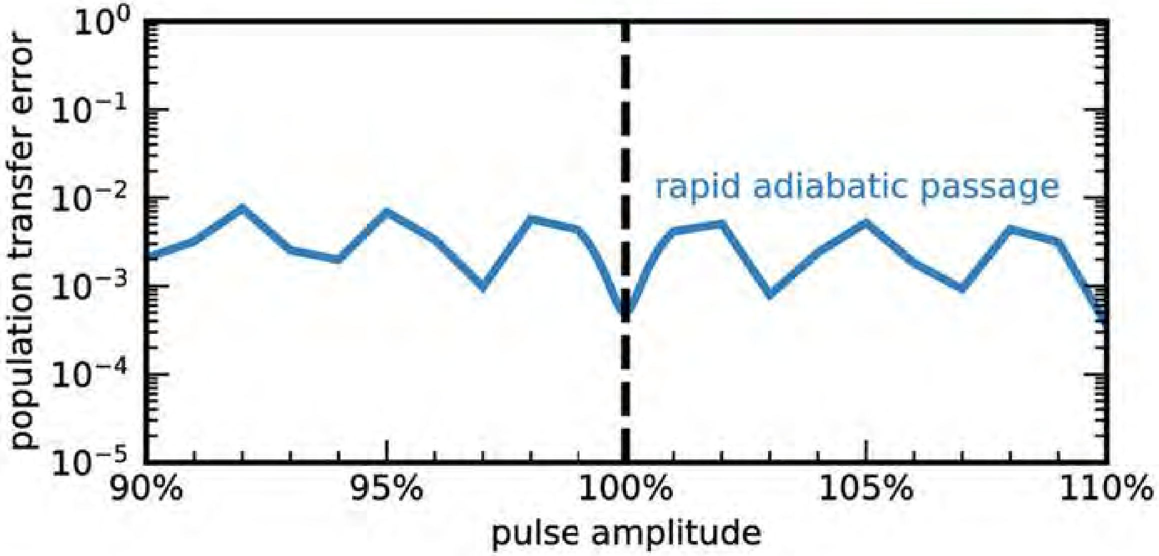
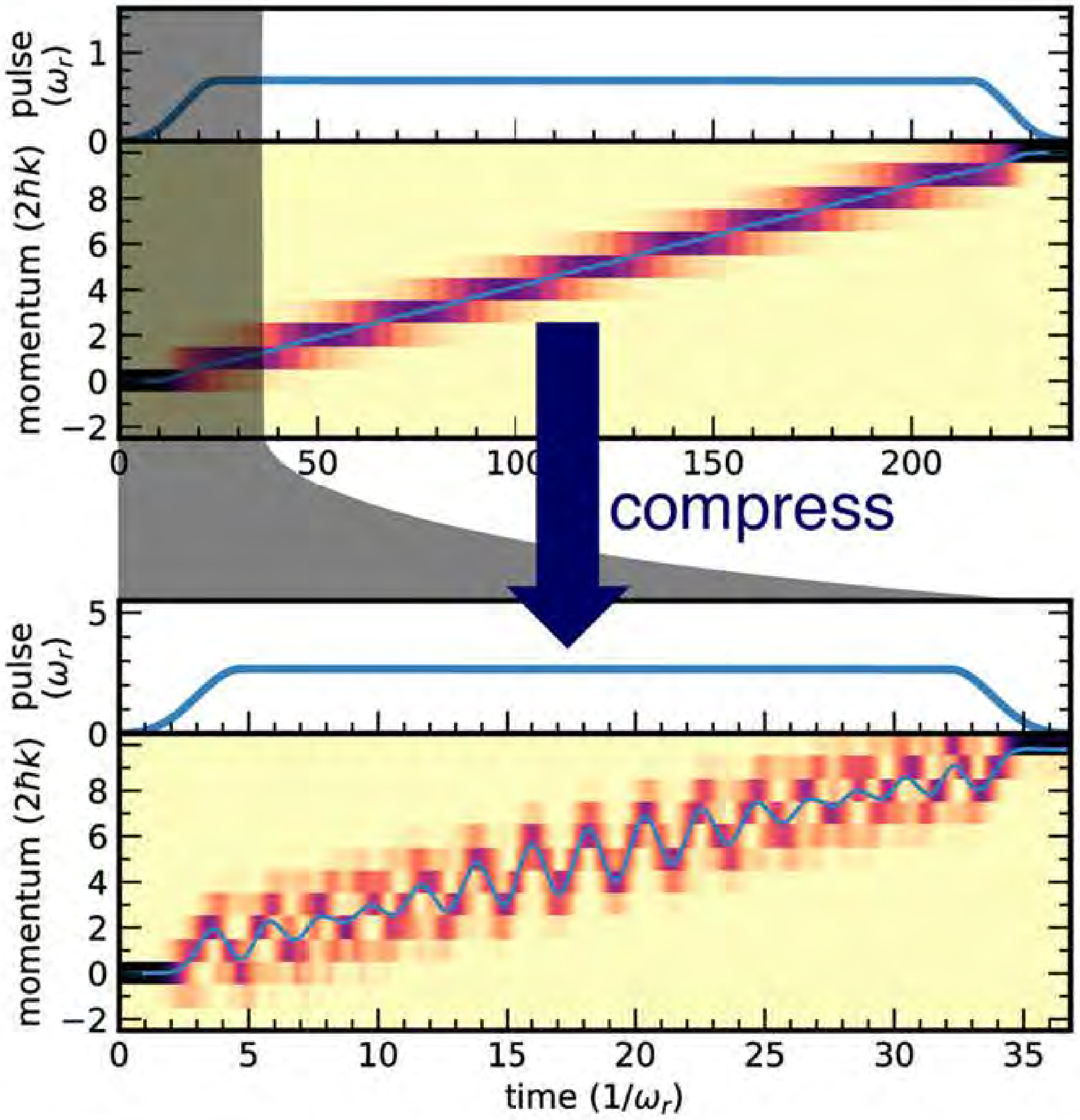
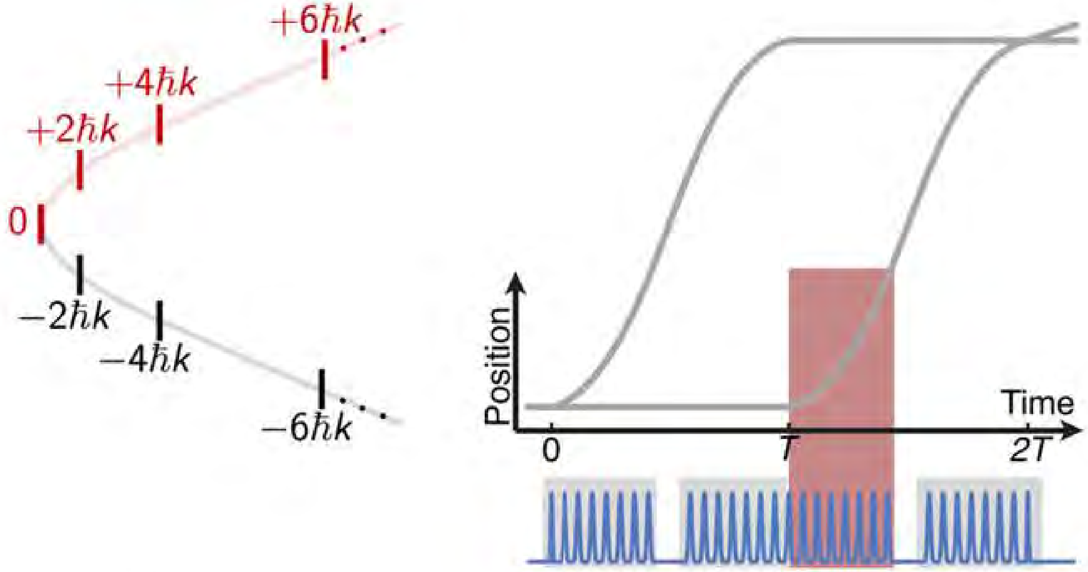

population transfer error
pulse amplitude
rapid adiabatic passage


pulse (ω_r)
momentum ($2\hbar k$)
compress
time ($1/\omega_r$)


$+6\hbar k$
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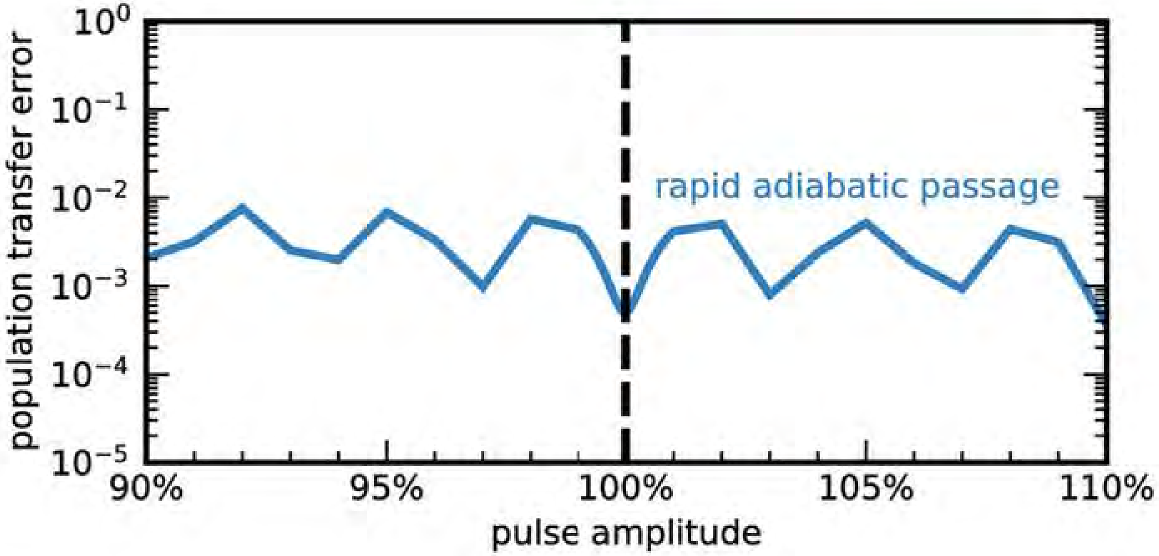
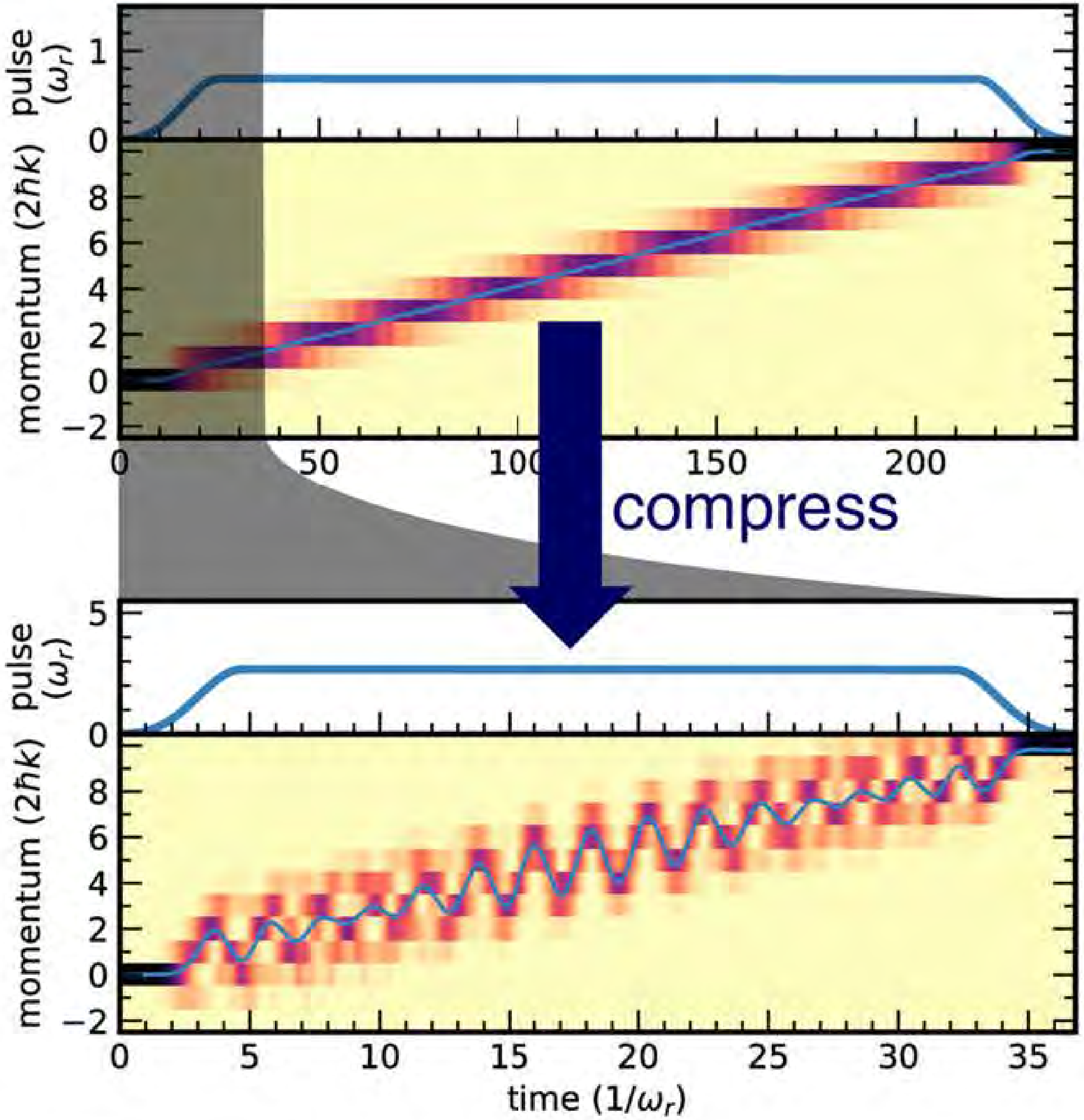

population transfer error
rapid adiabatic passage
pulse amplitude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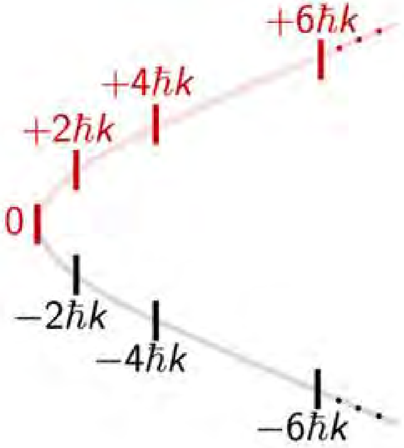
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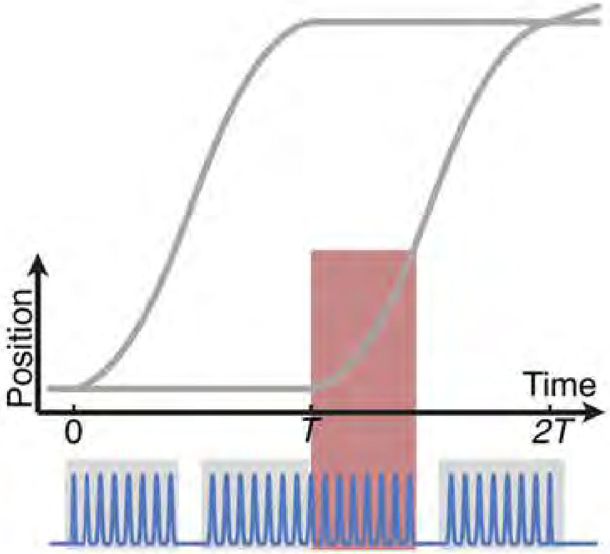
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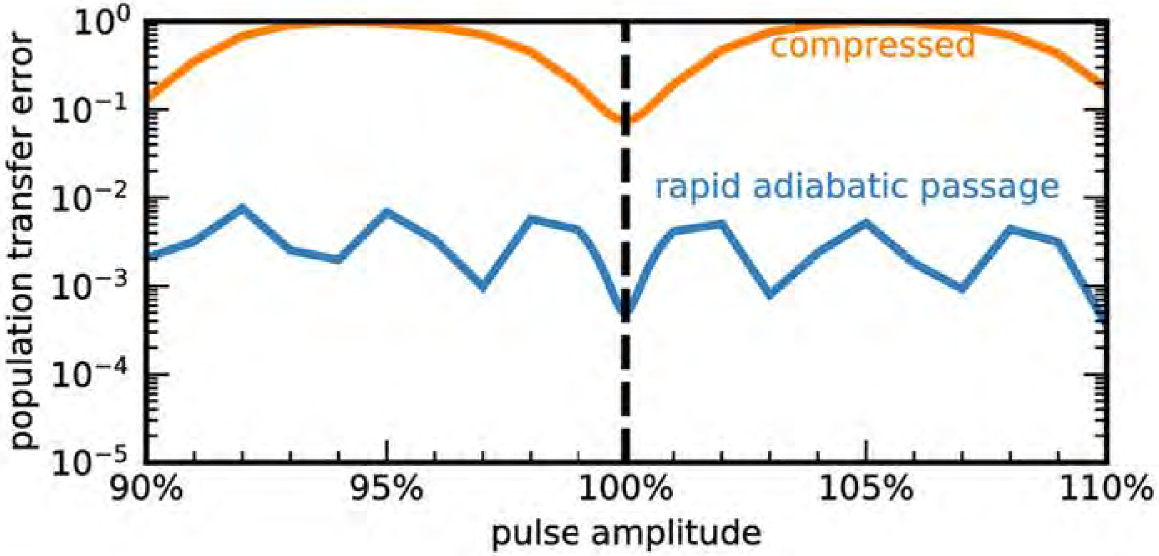
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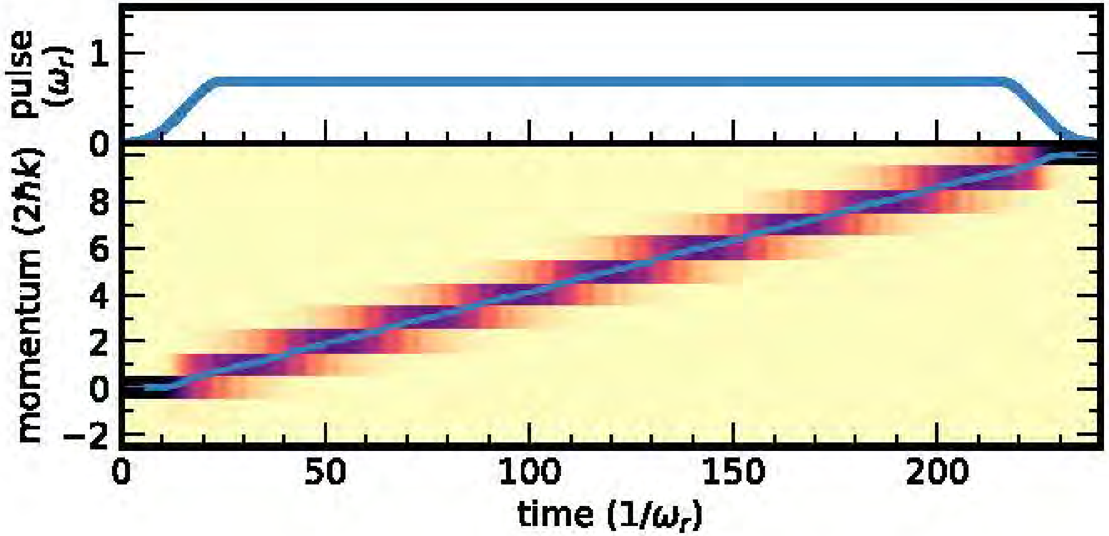
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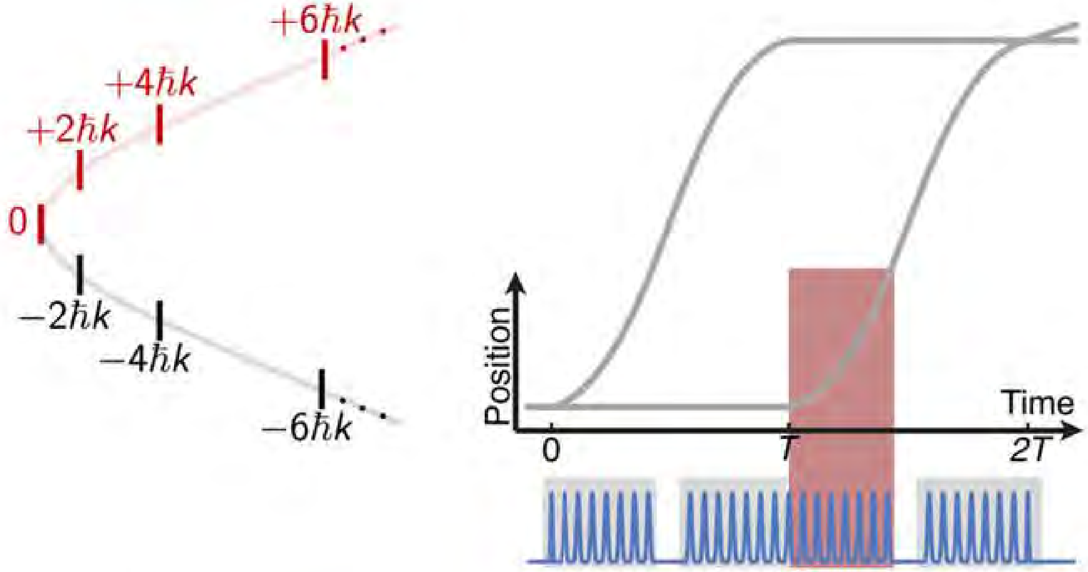
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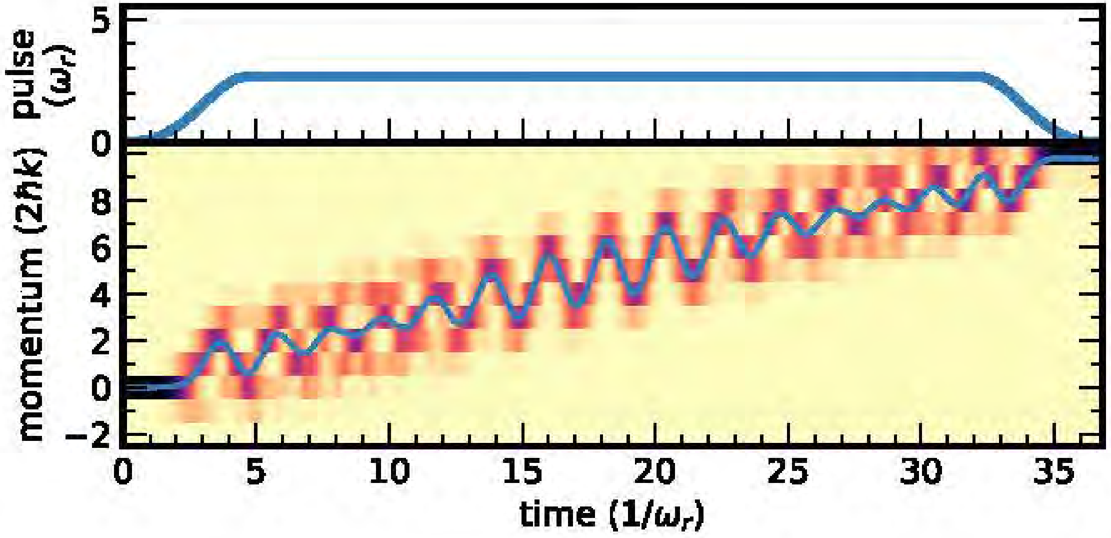
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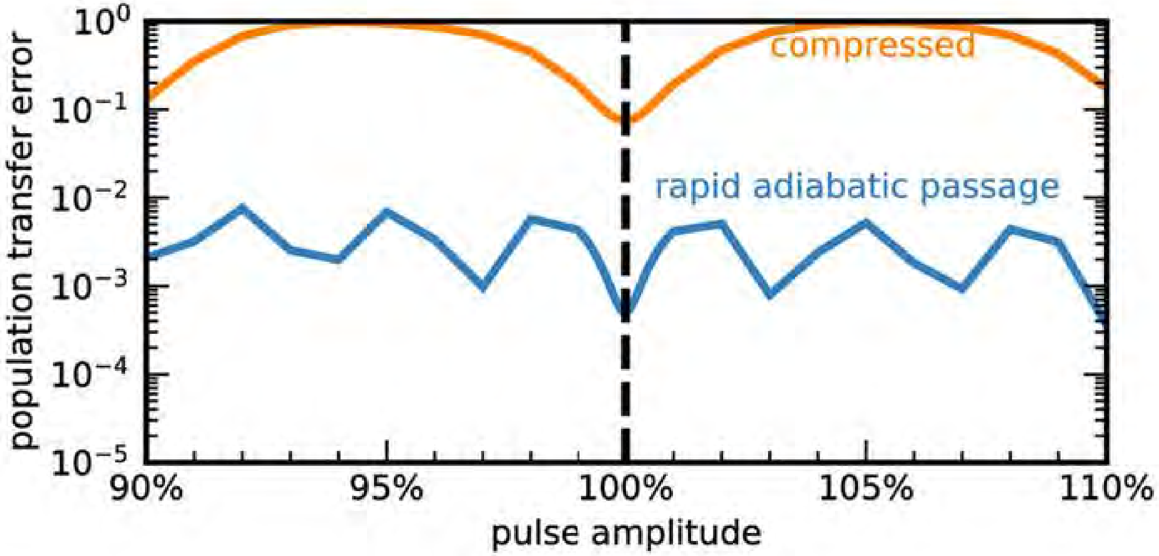
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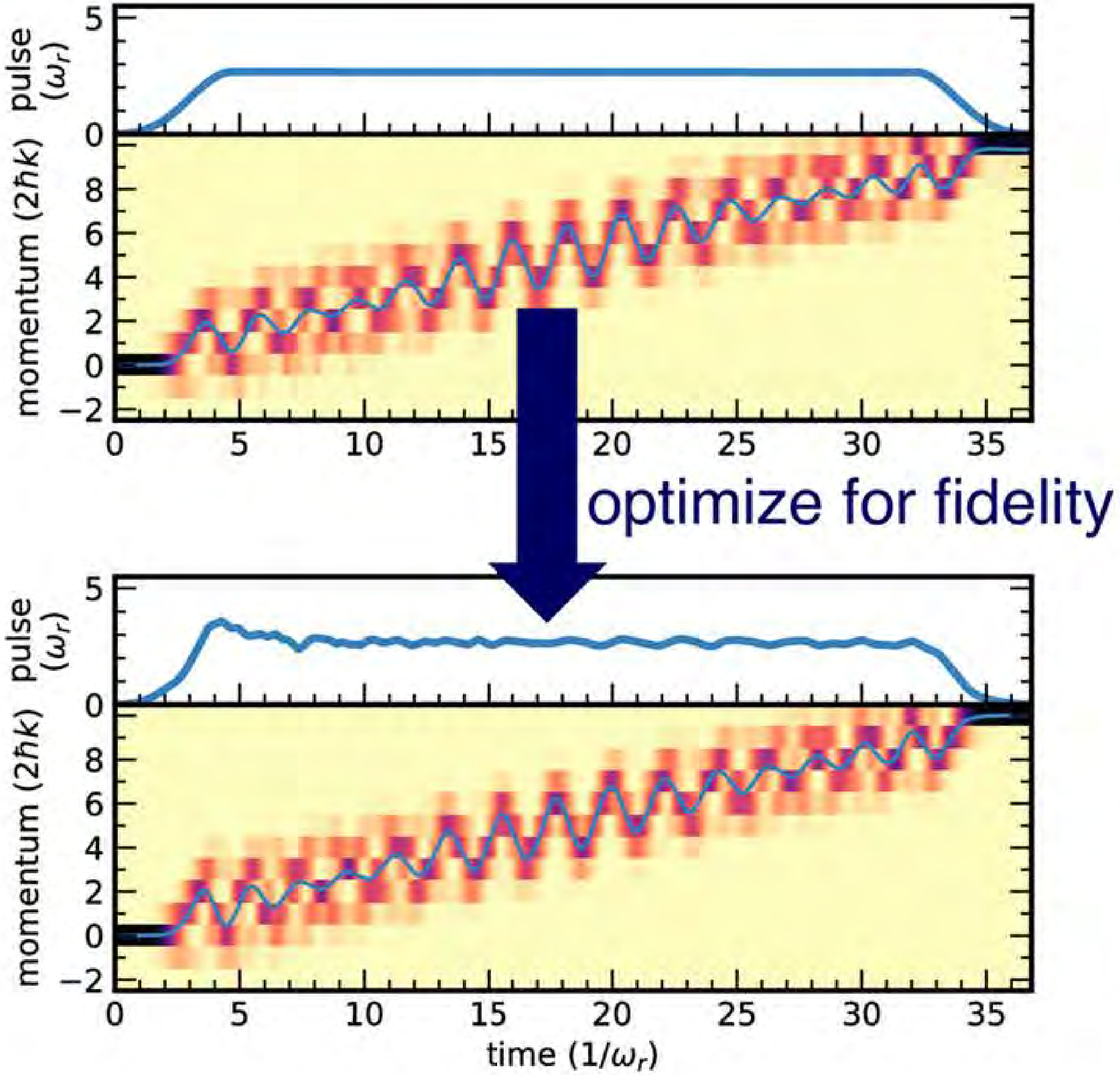
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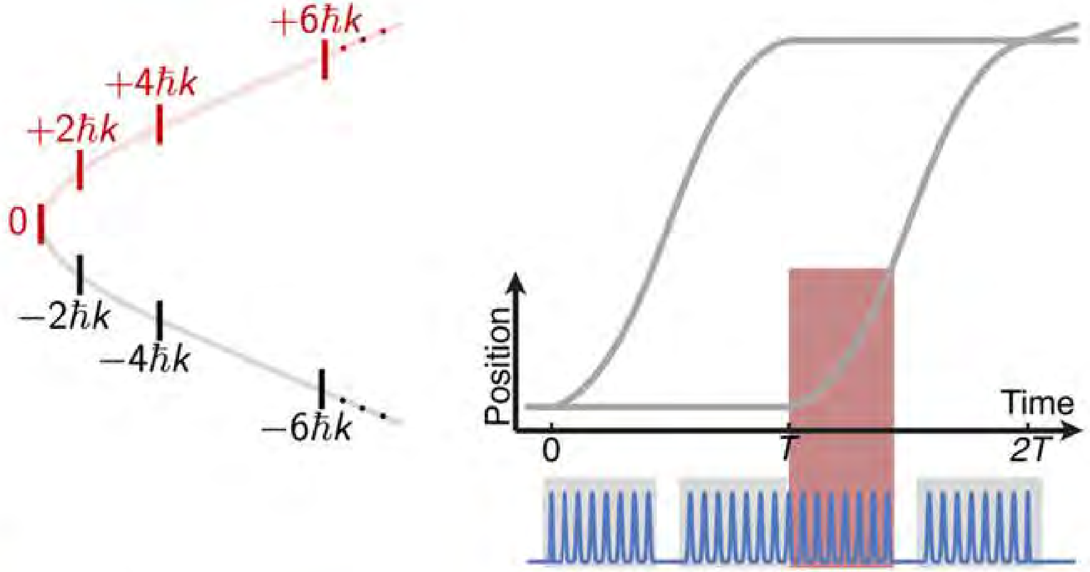
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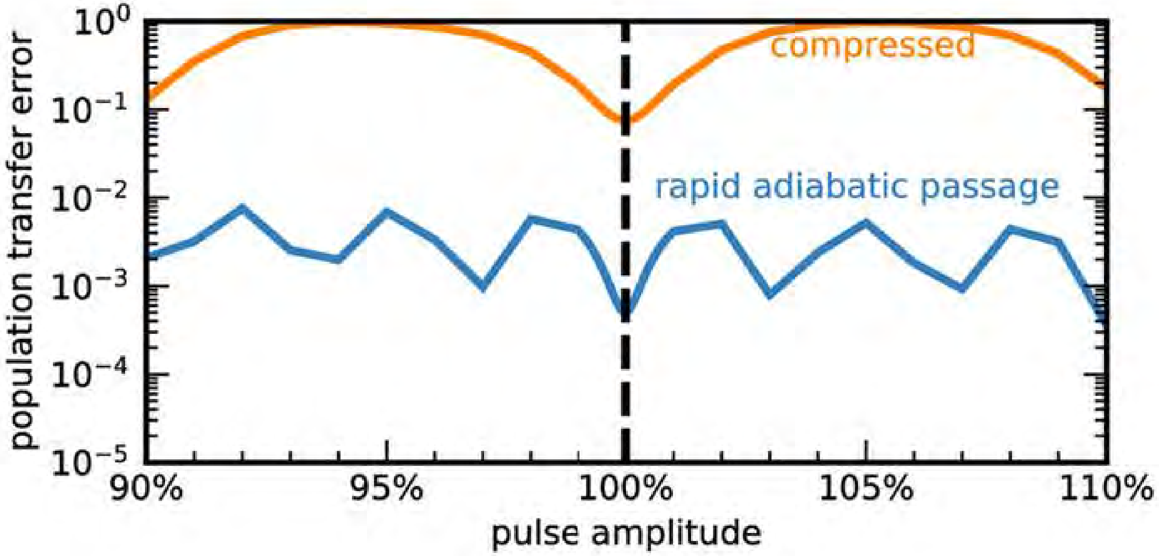
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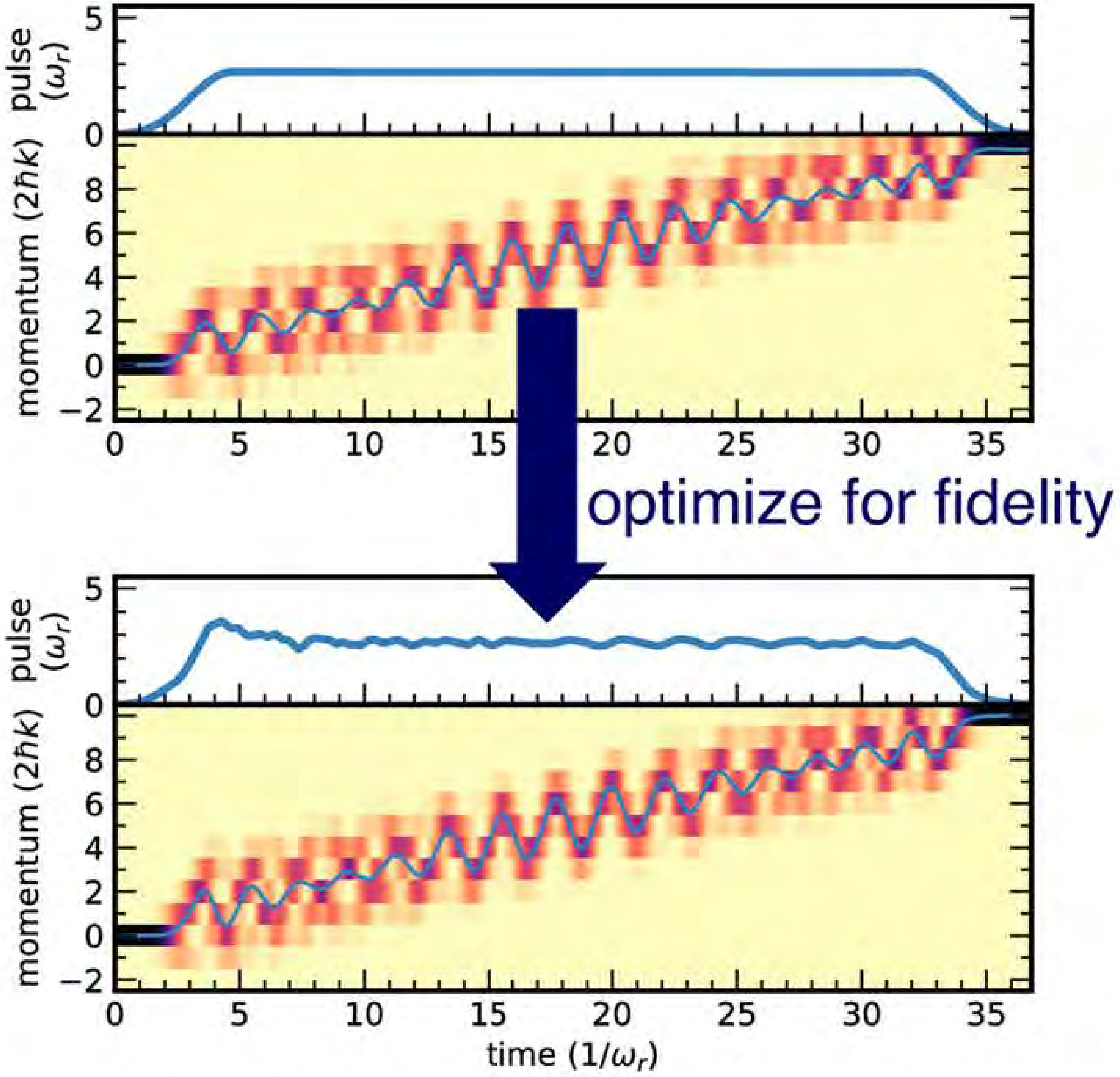

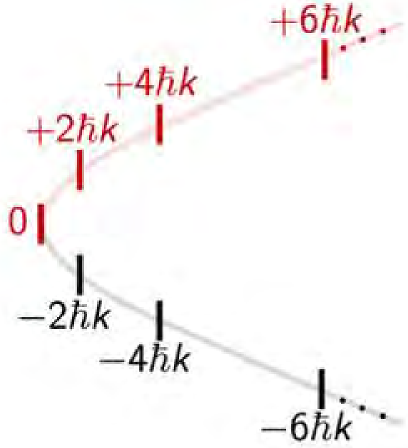

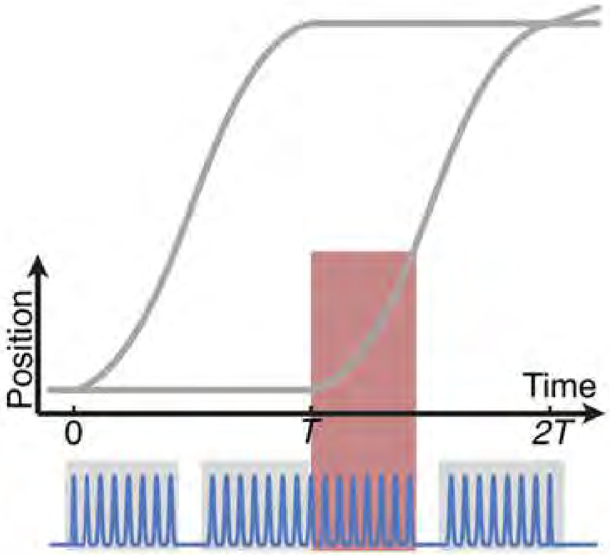

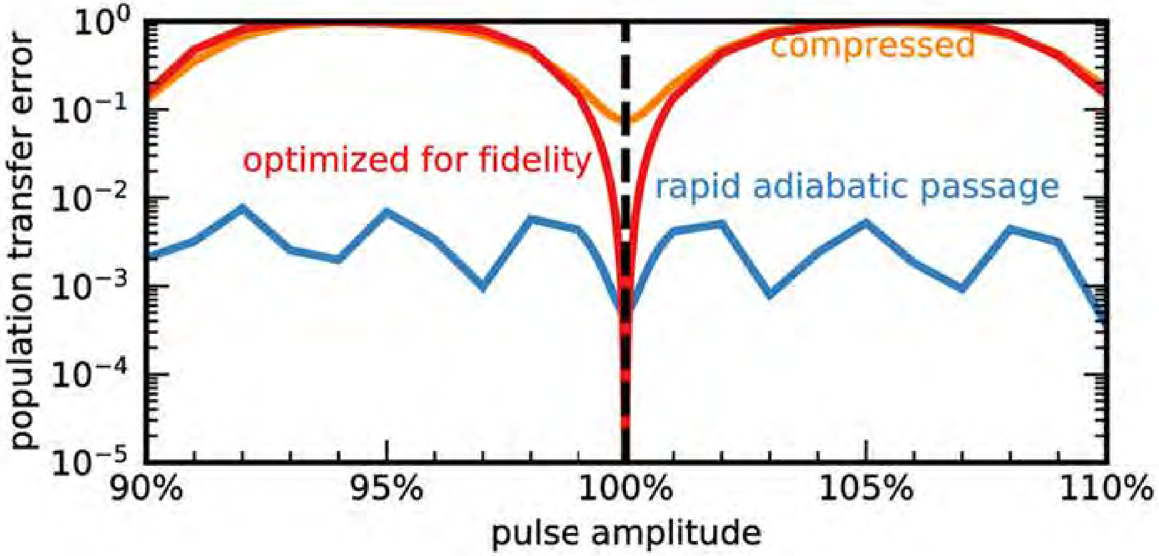

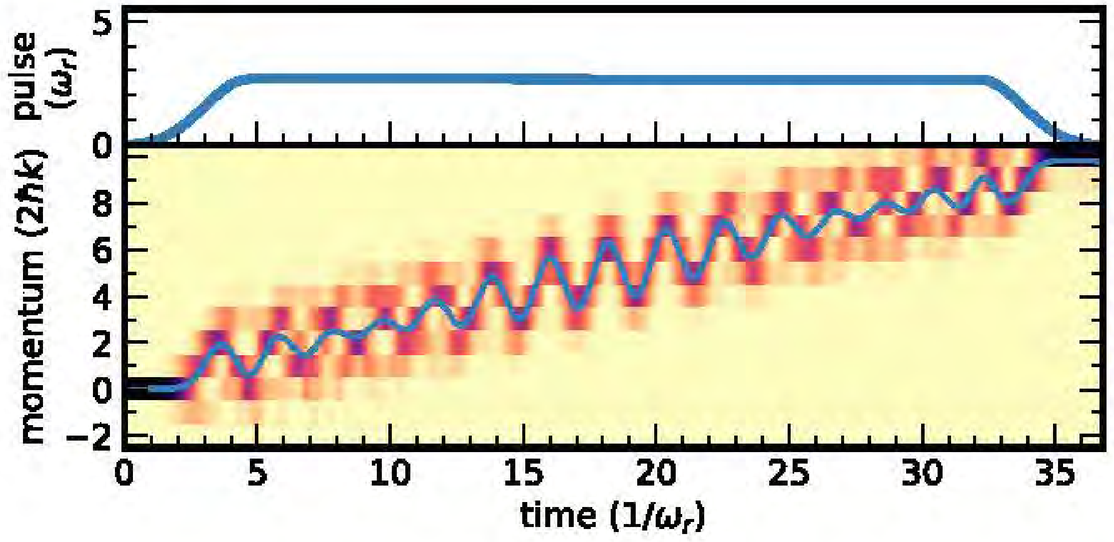
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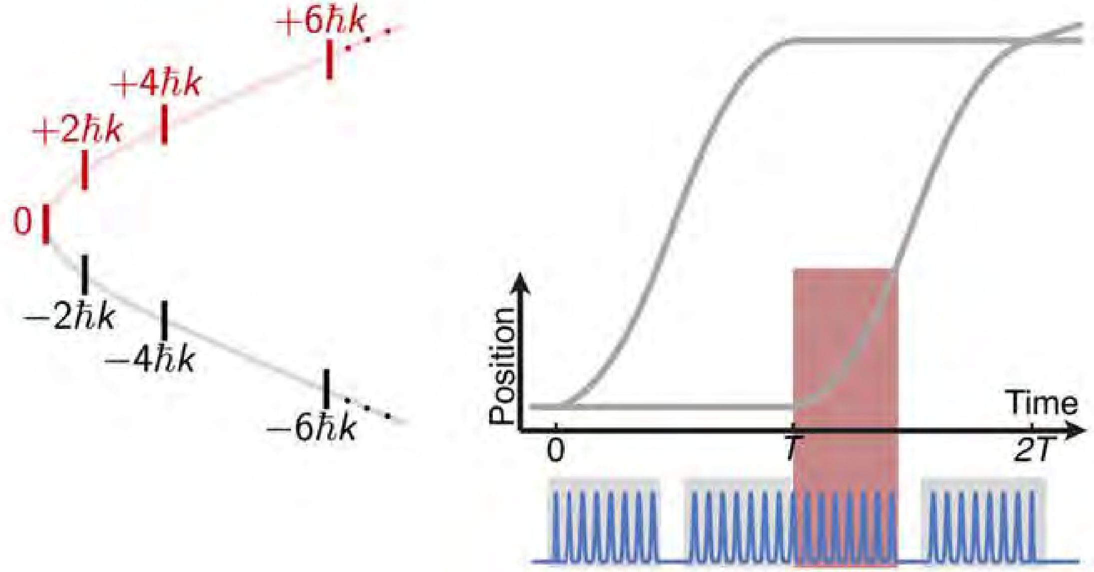
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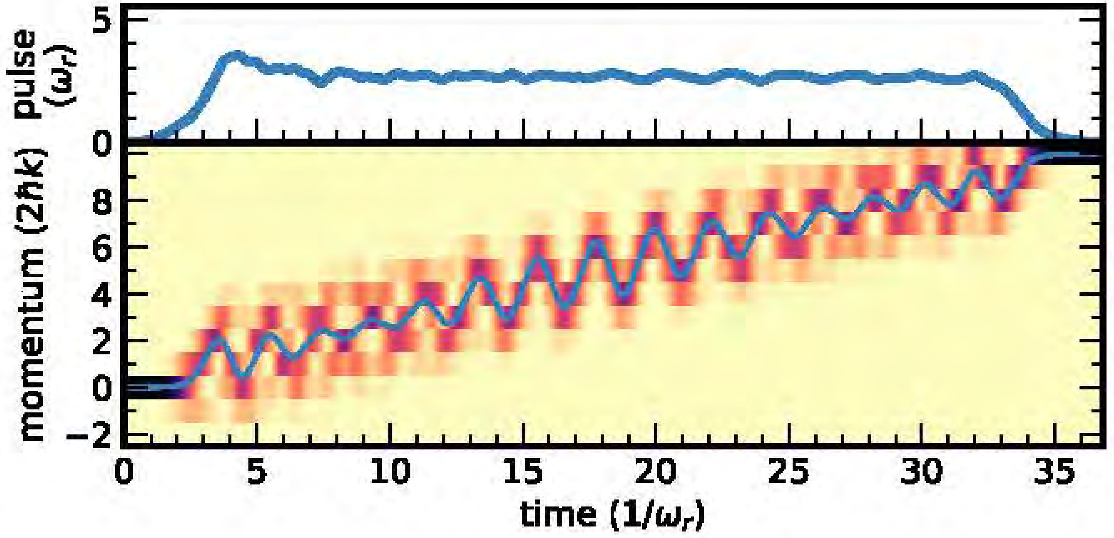
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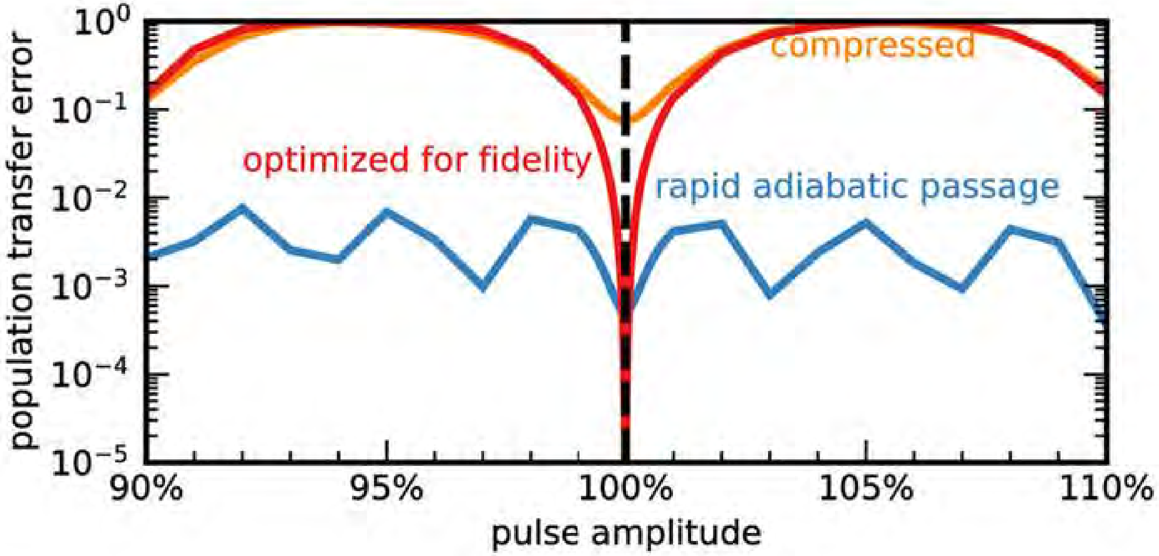
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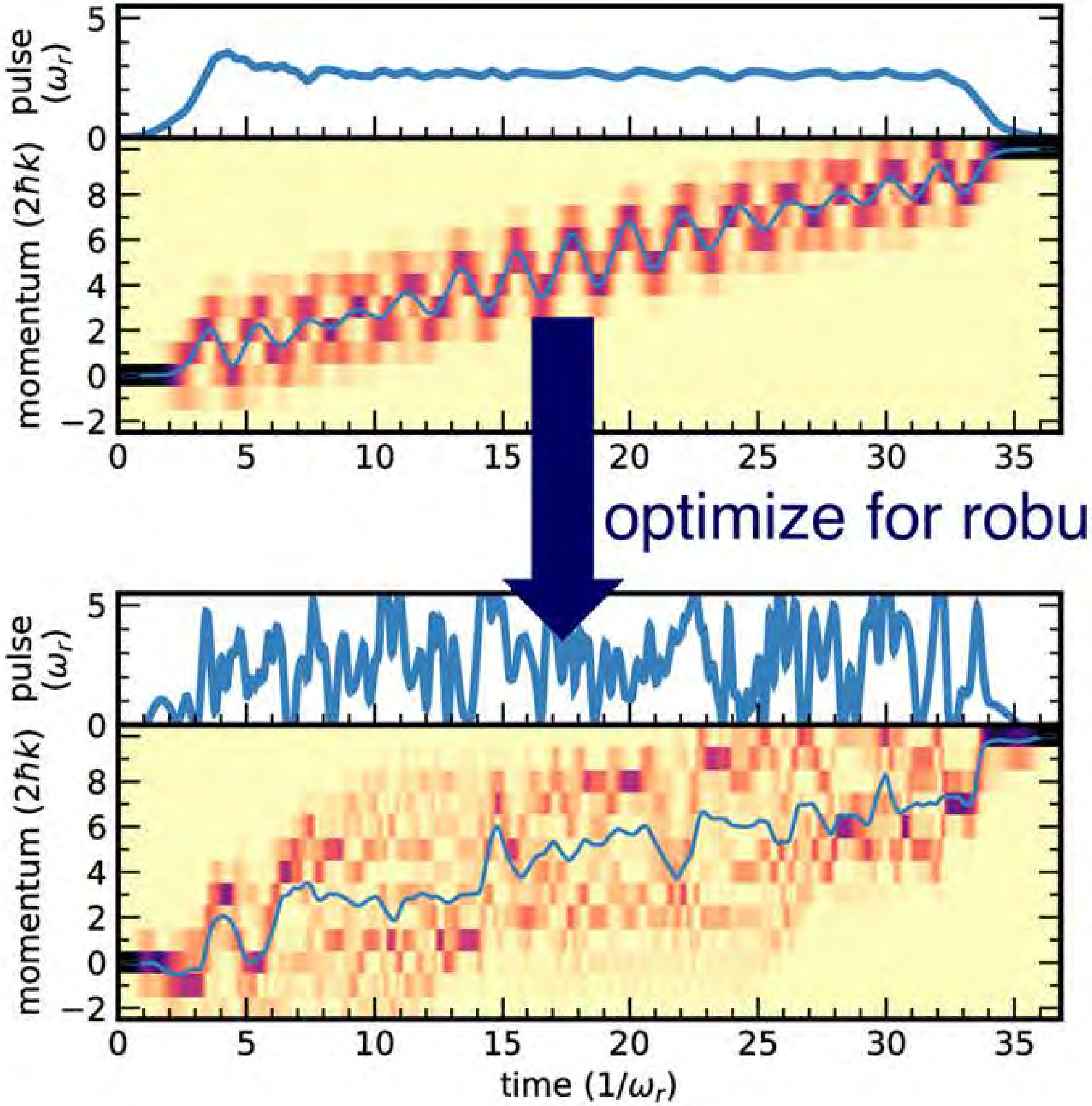

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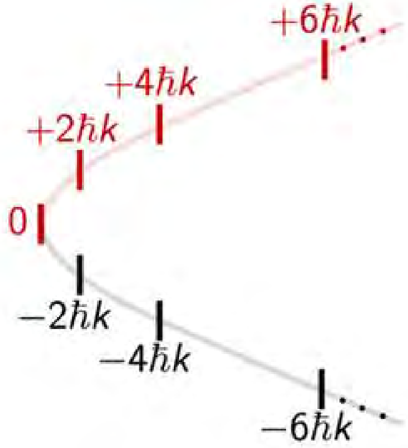

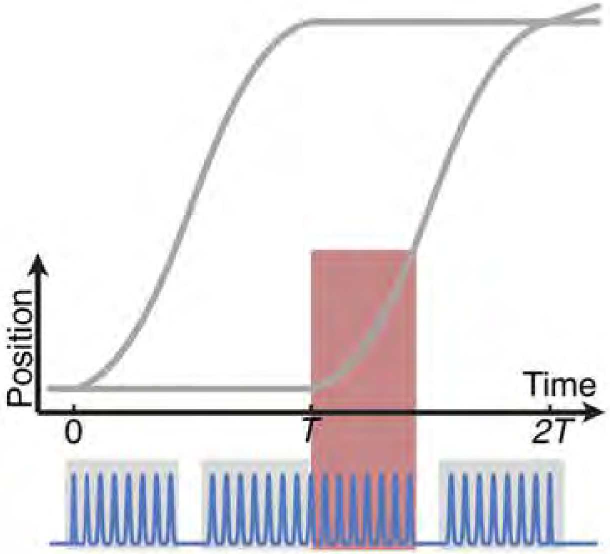

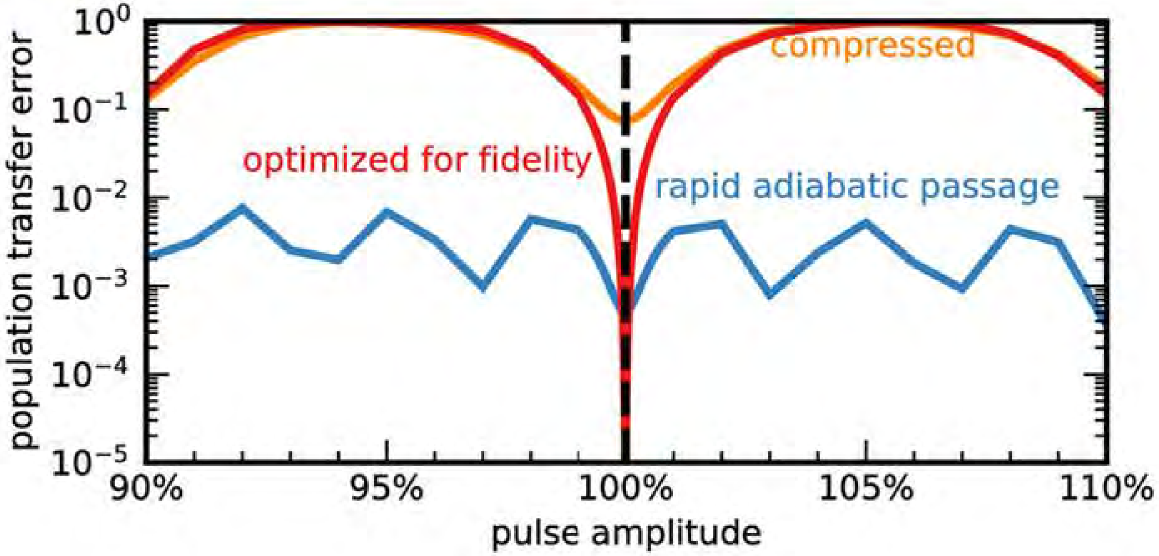

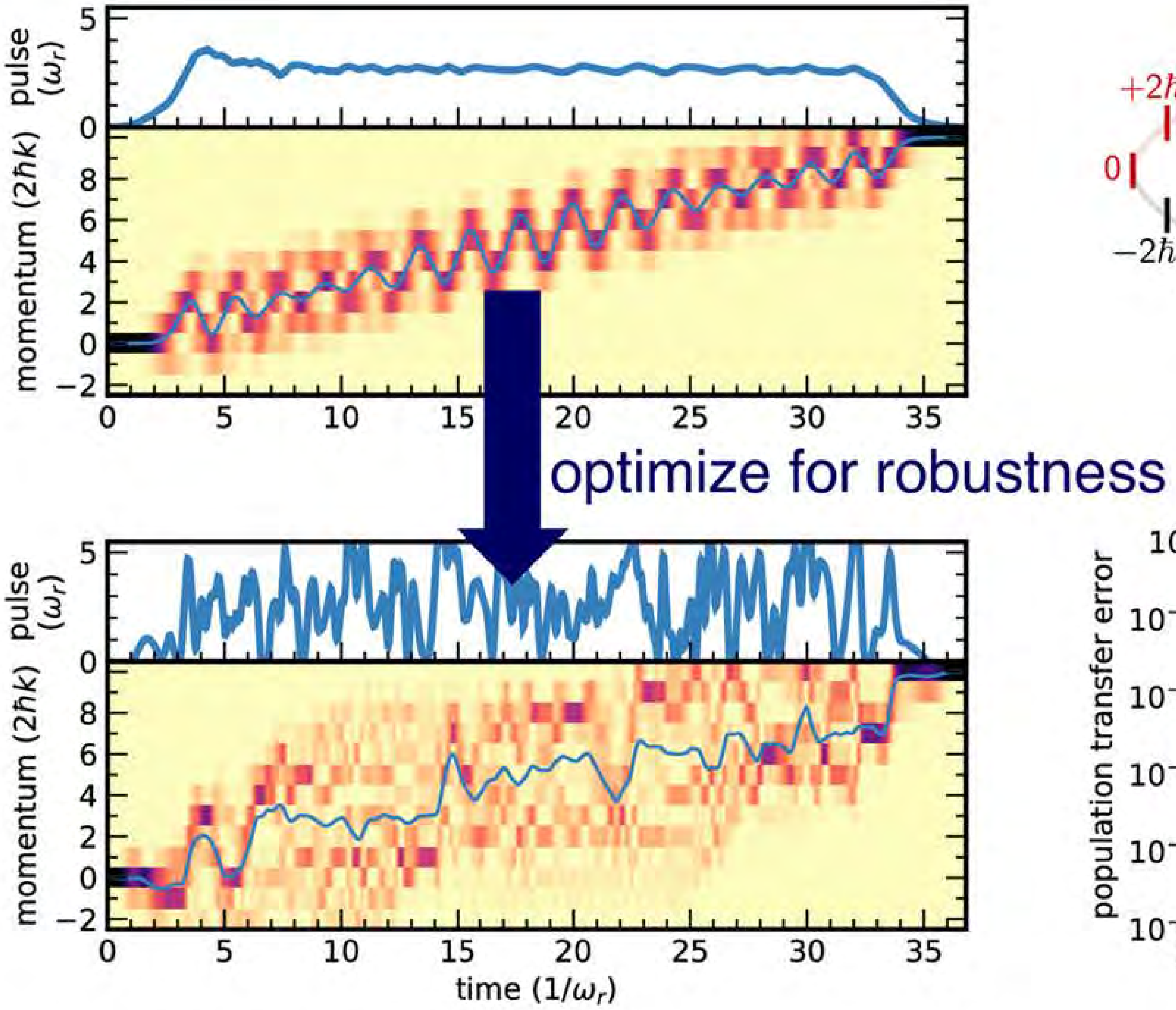
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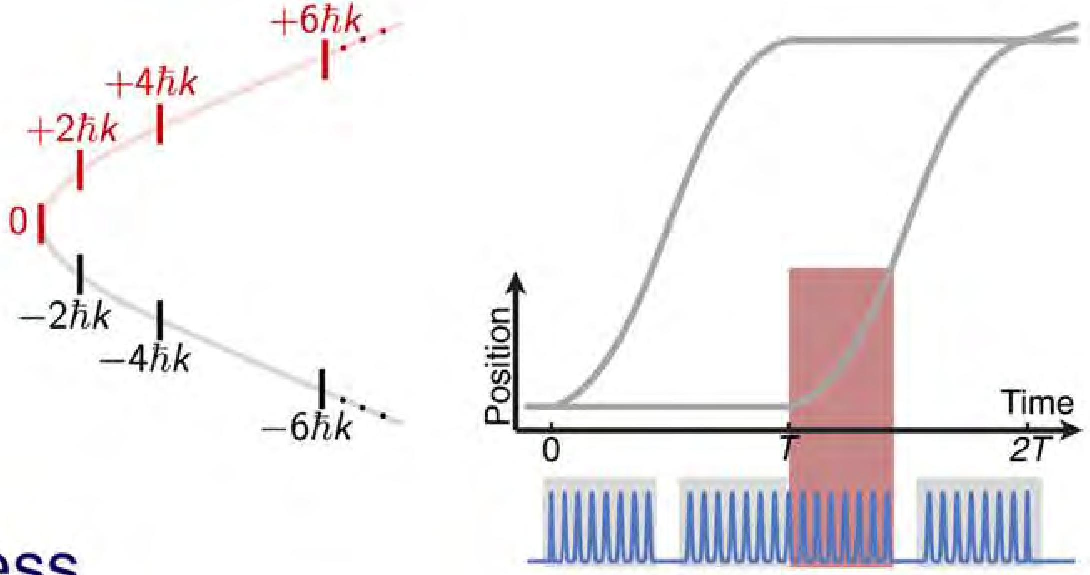
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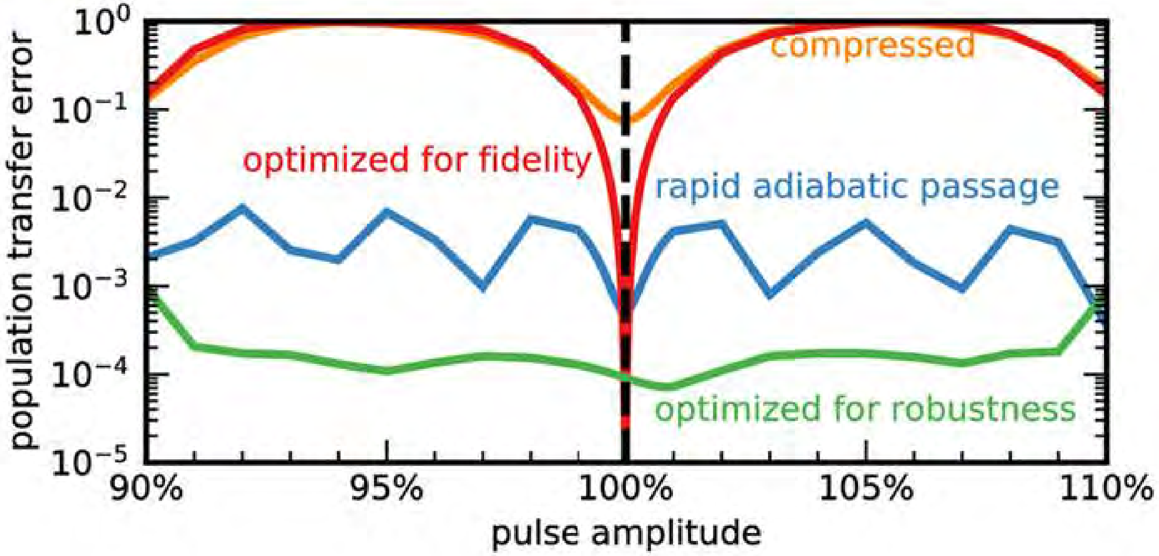
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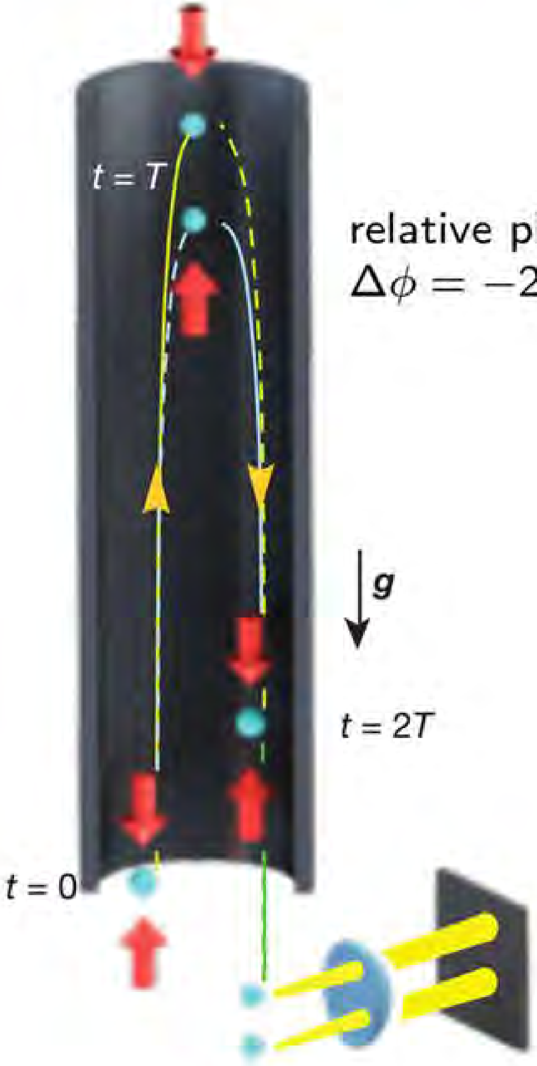
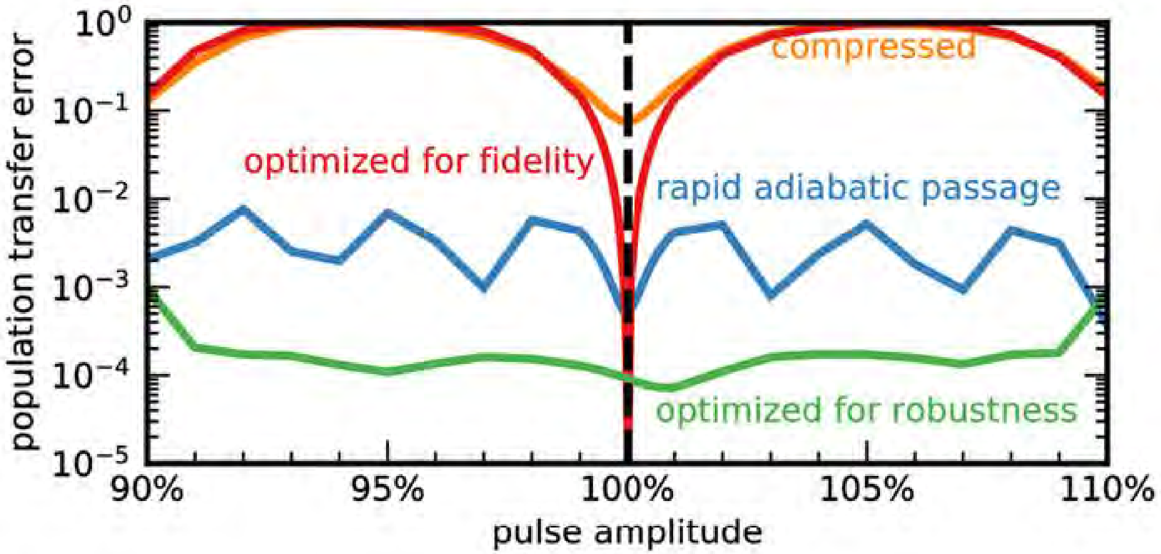
Conclusion



relative phase difference:
$\Delta\phi = -2k_{\max} g T^2$



- optimal control can compress pulses
  by order of magnitude while guaranteeing robustness
- Army applications:
  ultra-precise measurement of acceleration / gravity
  $\Rightarrow$ inertial navigation,
  satellite based gravitational sensing

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

Materials and Manufacturing Advancements to Demonstrate Objective Underbody Protection

Bryan Cheeseman and Megan Lynch

Team Leader

US Army Research Laboratory

23/08/2018

BACKGROUND: UNDERBODY THREAT

WWII

Korea

Vietnam

OIF

OEF

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BACKGROUND

1950's: Requirements for Aluminum Hull Combat Vehicles

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Ballistic Design Requirements for Mobile Vehicles

Substantial Protection Feasible
- Small Arms Rifles and Machine Gun
- Fragments from High Explosive, Shell
- Mortars
- Anti-Personnel Mines

Substantial Protection Impractical
- Artillery Kinetic Energy Projectiles (AP)
- Shaped Charge (HEAT)
- High Explosive Plastic (HEP)
- Anti-Tank Mines
- Nuclear

1960's: Deployed to Vietnam

https://www.awm.gov.au/collection/C243013

http://sitrep1.tripod.com/members_photo_album/Erik_Frisken.jpg

Between November 1967 and March 1970… mines accounted for 73% of all vehicle losses, including 1,342 M113s.

(Armor Magazine, Nuckols and Cameron, 2016)

While requirements did change from the 1950s to the 1980s, they were insufficient for operationally relevant threats seen in OIF/OEF.

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US ARMY AFFORDABLE PROTECTION FROM OBJECTIVE THREATS (APOT) MANTECH PROGRAM

OBJECTIVE

Mature affordable aluminum hull manufacturing technologies to defeat <u>objective</u> underbody blast threats and demonstrate <u>objective</u> level force protection.

Definition:

- APOT Threshold (T) > Operationally Relevant Threat
- APOT Objective (O) >> Operationally Relevant Threat

OPPORTUNITIES ADDRESSED

- ***Limited Manufacturing Technologies***
  - Current manufacturing technologies <u>not mature</u> enough to fabricate heavily protected combat vehicle structures
- ***Force Protection***
  - Fielded solutions <u>not sufficient</u> to protect against objective underbody blast attacks
  - Objective underbody threats require <u>thicker hull materials</u> and <u>new design concepts</u>
- ***Informed Decision Making** via Live Fire Tests*
  - Objective threats far exceeded prior understanding of structure performance
  - Understand the realm of “possibilities”

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APOT HULL MANUFACTURING

Minimize the propensity of common failure modes in aluminum hulls by maturation of manufacturing methods for thicker hulls

- Having minimal welds through the use of forging and forming;
- Utilizing improved weld processes for higher strength welds with minimal defects.

FORGING

FORMING

From Steel News, 2015

HIGH ENERGY BURIED ARC WELDING (HEBAW)

U.S. ARMY RDECOM ARL RESEARCH LABORATORY

MATERIAL CONSIDERATIONS: ARMOR ALLOYS FOR FORGING / FORMING

PEO-Ground Combat Systems: Conventionally weld-able, non-proprietary alloys

Alloy	MIL DTL	Pros	Cons
5083	46027K	Weldable, Extensive experience	Forge-ability constaints, Limited strength in thick section forgings
5059	46027K	Weldable, higher strength than 5083	Same as above, Proprietary
6061	32262	Forgeable, inexpensive	Poor strength in thick section, not qualified for ballistic welds
2219	46118E	Can forge large sections	Low elongation GMAW welds, little historical armor utilization
2519	46192C	High strength, can forge large sections	Low elongation GMAW welds, blast performance concerns
2139	32431	High strength, high toughness, good blast resistance	Low elongation GMAW welds Proprietary,
7085	32375	High strength, high toughness, good blast resistance, utilized for thick section forgings	Conventionally un-weldable, Proprietary.
7039	46063H	High strength	Stress corrosion cracking, blast resistance in T6 temper
7017	*32505*	High Strength	Stress corrosion cracking, blast resistance in T6 temper
7020	*32505*	Forge-able, capable of very thick sections, moderate strength, good toughness, weldable, Investigated as part of FTAS program	Appropriate temper required to minimize stress corrosion cracking

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ALUMINUM 7020 FOR FORMING & FORGING

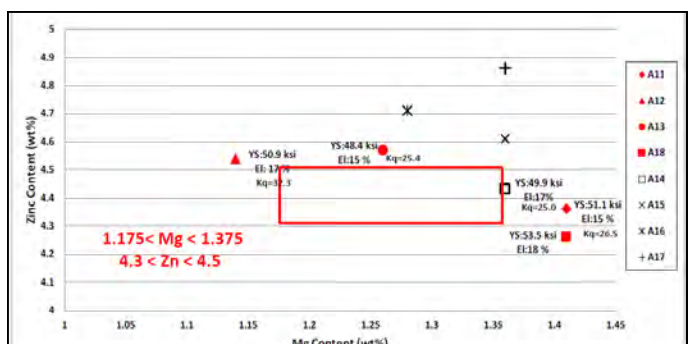
- Weld-able by conventional means
- Forge-able - thick section forgings produced by Aubert-Duval (France)
- Commodity armor alloy produced in Europe by Aleris, Constellium, Alcoa (UK) – but *never commercially produced in the US!*

ARL worked with ATI, Vista Metals and Constellium to quickly develop industrial scale processing parameters for domestic casting, forging and plate production

Developed target chemistry, homogenization practice, solution heat treat, quench and ageing practice.

ATI Inc.
Alloy Technology Innovations

7020 Chemistry and Thermomechanical Process Parameters Developed using Small Forgings



Very large billet casting done by Vista Metals.

VISTA METALS

FORGED HULL – CONCEPT TO COMPONENT

Risks

- Thickness distribution
- Geometry
- Component depth
- Lack of cold workability
- Ingot size and shape limits
- Ingot upsetting
- Preforming
- Process parameters
  - Temperature (piece/tool)
  - Tooling
  - Material handling
- Material Flow characteristics
- Residual stresses
- Quench Sensitivity
- Ingot chemistry
- Weld performance
- Side wall fill
- Die configuration
- SHT&Q parameters
- Ageing parameters
- Equipment limitations
- Machining distortions

Activities

- Component Design
- Design for manufacture
- Tool steel acuisition
- Forging analysis
- Tooling design
- Tooling fabrication
- Chemistry development
- Ingot acquisition
- Ingot upsetting
- Process flowpath
- Risk assessment/mitigation
- Preforming
- Die forging
- Component clean-up
- Residual stress analysis
- Distortion analysis/mitigation
- SHTQ & Age
- Straightening
- Machining
- Shipping
- Integration (Bob Sled, BH&T)
- Blast testing

From this…

…to this in 12 months!

FORMED HULL – CONCEPT TO COMPONENT

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Constellium Capable of very large plate production for forming single piece hulls

- Rapidly developed the US ingot casting and rolling parameters for aluminum alloy 7020 production at Ravenswood, WV
- Produced all 7020-T651 plate for the effort.
- Produced the largest aluminum armor plate ever for formed hull trials.

From this…

Risks

- Geometry
- Bend radius/thickness limits
- Formability vs. ageing
- Material flow characteristics
- Residual stresses
- Weld performance
- Die configuration
- SHT&Q parameters
- Ageing parameters
- Press limitations
- Machining distortions

Activities

- Design for manufacture
- Forming analysis
- Die design / manufacture
- Ingot processing
- Process flow path
- Risk assessment/mitigation
- Residual stress analysis
- Forming
- Machining
- SHTQ & Age
- Shipping
- Integration (Bob Sled, BH&T)
- Blast testing

AMRO FABRICATING CORPORATION

U.S. ARMY RDECOM ARL RESEARCH LABORATORY

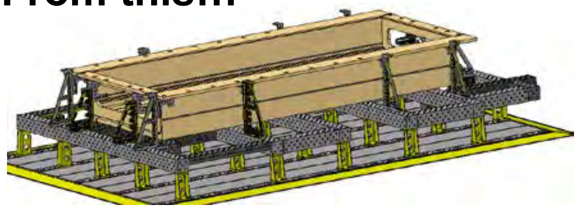
HIGH ENERGY BURIED ARC WELDED (HEBAW) HULL – CONCEPT TO COMPONENT

HEBAW

- BAE has developed an automated, high current density gas metal arc welding (GMAW) technology for 5083 and 5059 alloys

- HEBAW advantages of conventional GMAW processes
  - High deposition rate (70-90% reduction in number of weld passes)
  - High weld penetration
  - 90% reduction in weld time
  - Reduced filler metal required
  - Less heat input → less distortion
  - Robotic – controlled, repeatable
  - Reduced weld defects

From this…



Thickest welded aluminum hull ever fabricated

U.S. ARMY RDECOM ARL RESEARCH LABORATORY

MANUFACTURING TECHNOLOGY ACHIEVEMENTS

Forged

Largest aluminum die forging ever produced

Forge hulls capable of integrated O protection

- Forged lower hull successfully manufactured and tested at O
- Forged Ballistic Hull & Turret (BH&T) fabricated; tested at O
- Integrate Tencate Active Blast Defense System (ABDS) into BH&T and re-tested at O
- Integrate Sloman Active Blast & Ballistic System (ABBS) onto BH&T and re-re-tested at O
- Machine forged lower hull to reduced areal density, test at T

Formed

First formed aluminum tracked combat vehicle hull produced

Form hulls having integrated T, kit to O protection

- Formed lower hull successfully manufactured and tested at T
- Formed lower hull + kit successfully manufactured and tested at O
- Fabricate formed BH&T and test at O

Welded

Thickest welded lower combat vehicle hull ever produced

High Energy Buried Arc Weld (HEBAW) hulls having integrated T, kit to O

- HEBAW hull successfully manufactured and tested at T
- HEBAW hull + kit successfully manufactured and tested at O
- HEBAW tested (on weld) at T

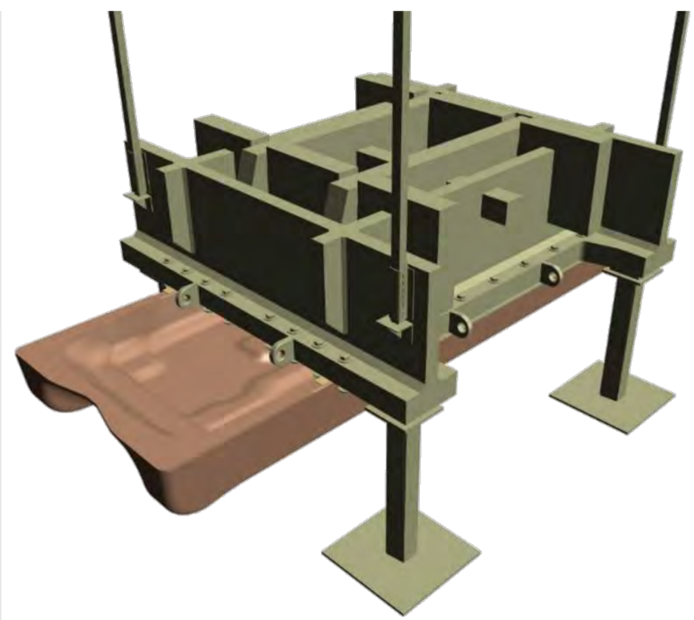
9 full scale lower hull structures, including 2 ballistic hull & turrets (BH&Ts), fabricated and tested. Demonstrated T and O underbody blast resistance!

UNCLA

U.S. ARMY RDECOM ARL RESEARCH LABORATORY

LIVE FIRE TESTING OF HULLS

All hulls were mounted on a massive (44 ton) test fixture (the Bobsled) and tested with both Threshold and Objective underbody charges to validate the performance of the manufactured hulls.



HULL BLAST RESULTS

MANUFACTURING PATH	POST-TEST HULL	OBSERVATION
Forging		Minimal permanent deformation
Forming		~Minimal permanent deformation
HEBAW		Moderate permanent deformation

BALLISTIC HULL AND TURRETS (BH&T'S)

•The formed and the forged hulls were manufactured into BH&Ts

•The BH&Ts were outfitted with a number of energy absorbing technologies, ATDs and instrumentation.

•BH&T's were live fire tested at Objective underbody levels.

•Force protection was demonstrated.

SUMMARY

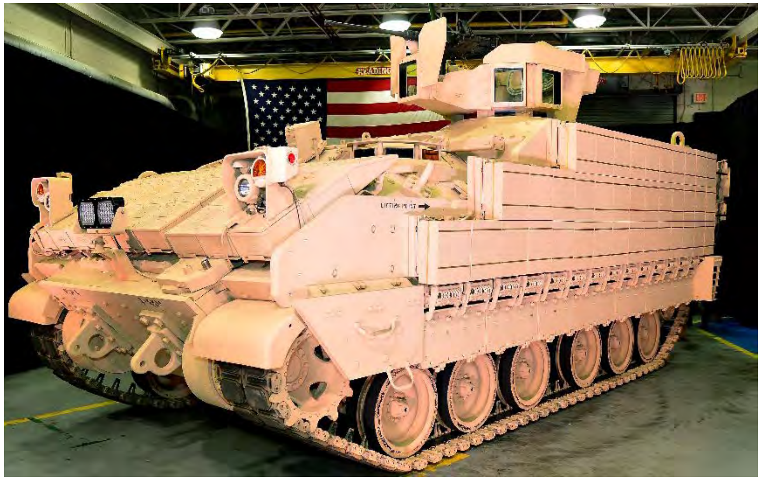
- The Affordable Protection from Objective Threats (APOT) ManTech effort matured three manufacturing processes for lower hulls having
- Objective level blast resistance and validated the processes and resultant hulls through live fire testing.

- Through collaboration of multiple agencies, nations and small and large businesses, a number of DoD efforts were aligned to develop and demonstrate Objective level underbody blast protection.
- Results were transitioned to TARDEC, PEO Ground Combat Systems, US Army TRADOC and vehicle OEMs.

TRANSITION & IMPLEMENTATION

- TRADOC Maneuver Center of Excellence wrote requirements based on the results demonstrated as part of APOT.

- BAE implemented design elements and manufacturing processes matured as part of APOT into the Armored Multi-purpose Vehicle (AMPV) lower hull.



https://www.baesystems.com/en-us/multimedia/armored-multi-purpose-vehicle-roll-out

ACKNOWLEDGEMENTS

U.S. ARMY RDECOM TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
ARL TARDEC
DARPA
MANEUVER CENTER OF EXCELLENCE FORT BENNING
ATC
FUTURE FIGHTING VEHICLE
STATE OF ISRAEL MINISTRY OF DEFENSE
BAE SYSTEMS INSPIRED WORK
ALCOA
ARCONIC
Constellium
AMRO FABRICATING CORPORATION
VISTA METALS
ATI Ladish Forging
TENCATE
UAC UNIVERSAL ALLOY CORPORATION
CORVID TECHNOLOGIES
ATI Inc. Alloy Technology Innovations
PRATT MILLER

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ARL RESEARCH LABORATORY

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

FORWARD LOOKING SYNTHETIC APERTURE RADAR (FLSAR) CONCEPT FOR LANDING IN DEGRADED VISUAL ENVIRONMENTS (DVE)

Traian Dogaru, Calvin Le and Anders Sullivan

U.S. Army Research Laboratory

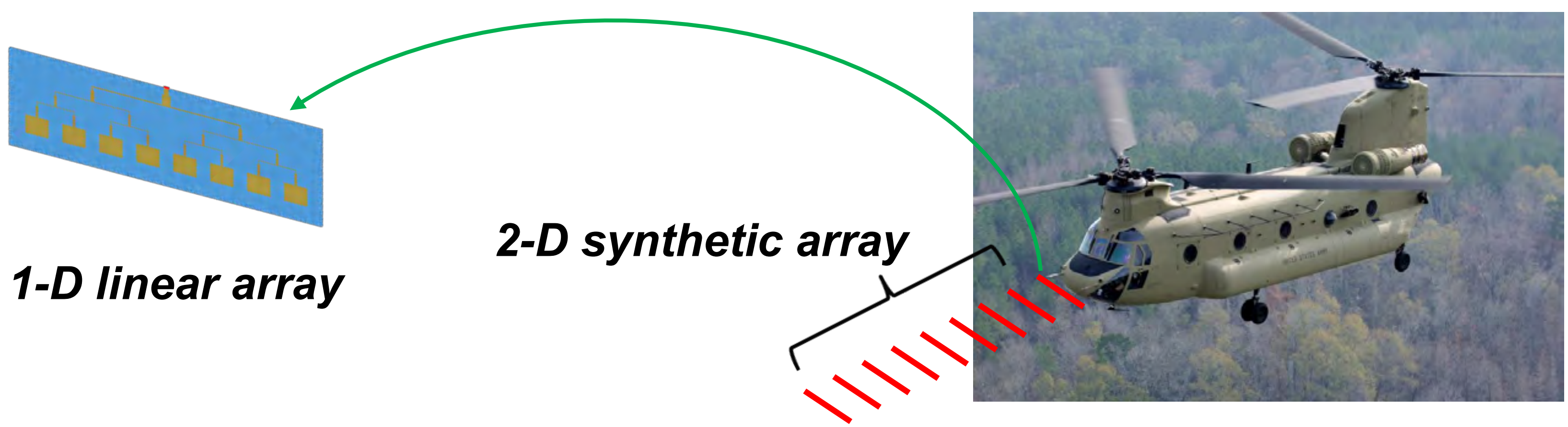
23 August 2018

MOTIVATION

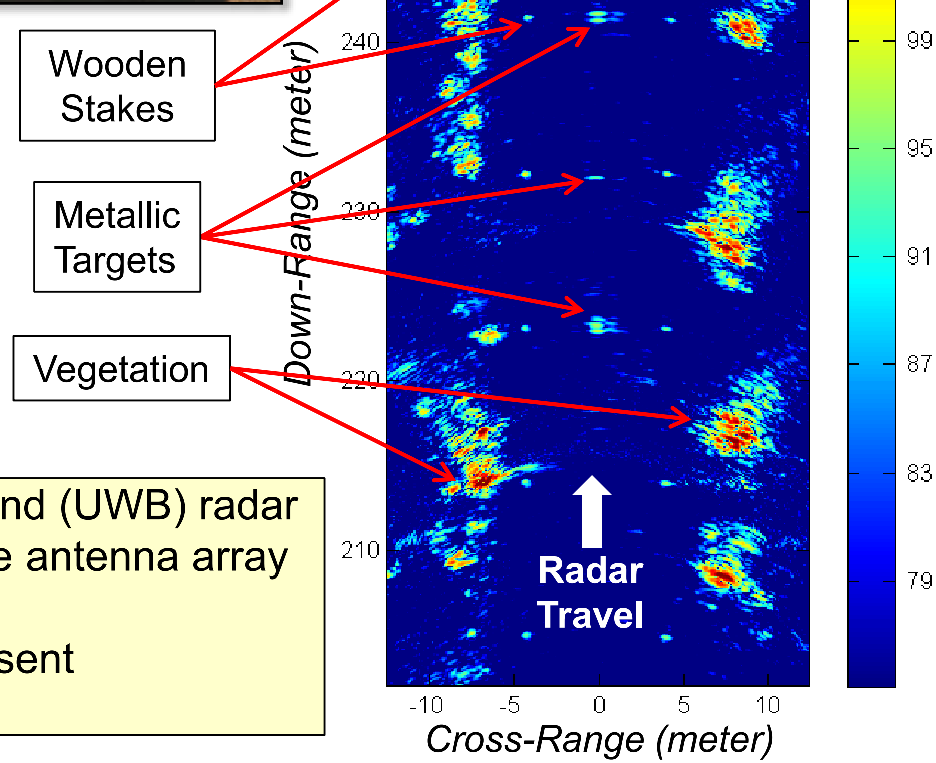
- Survivability of Future Vertical Lift Platforms is one of the Army's modernization priorities
- Rotorcraft crashes caused by degraded visual environments (DVE) conditions account for a large number of casualties to US and allied forces
- We propose the development of a millimeter-wave (MMW) radar sensor to assist helicopter landing in DVE
- Current state-of-the-art in aircraft landing sensors:
  - Forward-looking infrared (FLIR) – cannot see through thick dust
  - Passive MMW scanning arrays – no range info, limited resolution
  - Active MMW radar based on 2-D scanning arrays – complex and costly
- The on-going DVE-M Army program integrates multiple sensors on one platform
- Landing in heavy brownout conditions is still a capability gap
- Current radar systems does not meet all SWAP-C and performance requirements

WHY FORWARD LOOKING SAR FOR DVE

- Our proposed solution: linear antenna array combined with forward-looking synthetic aperture radar (FLSAR) processing
- Different operation from both traditional side-looking SAR and 2-D scanning arrays
- Radar system operating in a MMW frequency band
- Simpler, less expensive, low SWAP, more robust solution for 3-D terrain mapping
- Emphasis shifted from hardware complexity (physical beamforming) to signal processing (computational beamforming)
- FLSAR requires accurate timing and position information to maintain coherent processing



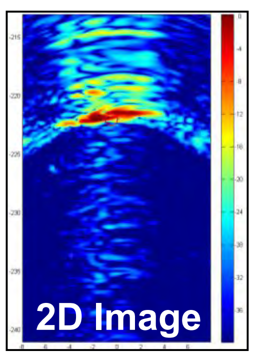
HISTORY OF FORWARD LOOKING RADAR AT ARL



- Low-frequency (0.5 – 2 GHz), ultra-wideband (UWB) radar
- 2 transmitters and 16 receivers in 2-m-wide antenna array
- Average power ~ 1 W, range up to 30 m
- System development between 2006 to present
- Applications: FOPEN, STTW, GPEN

FROM UWB TO MMW FLSAR

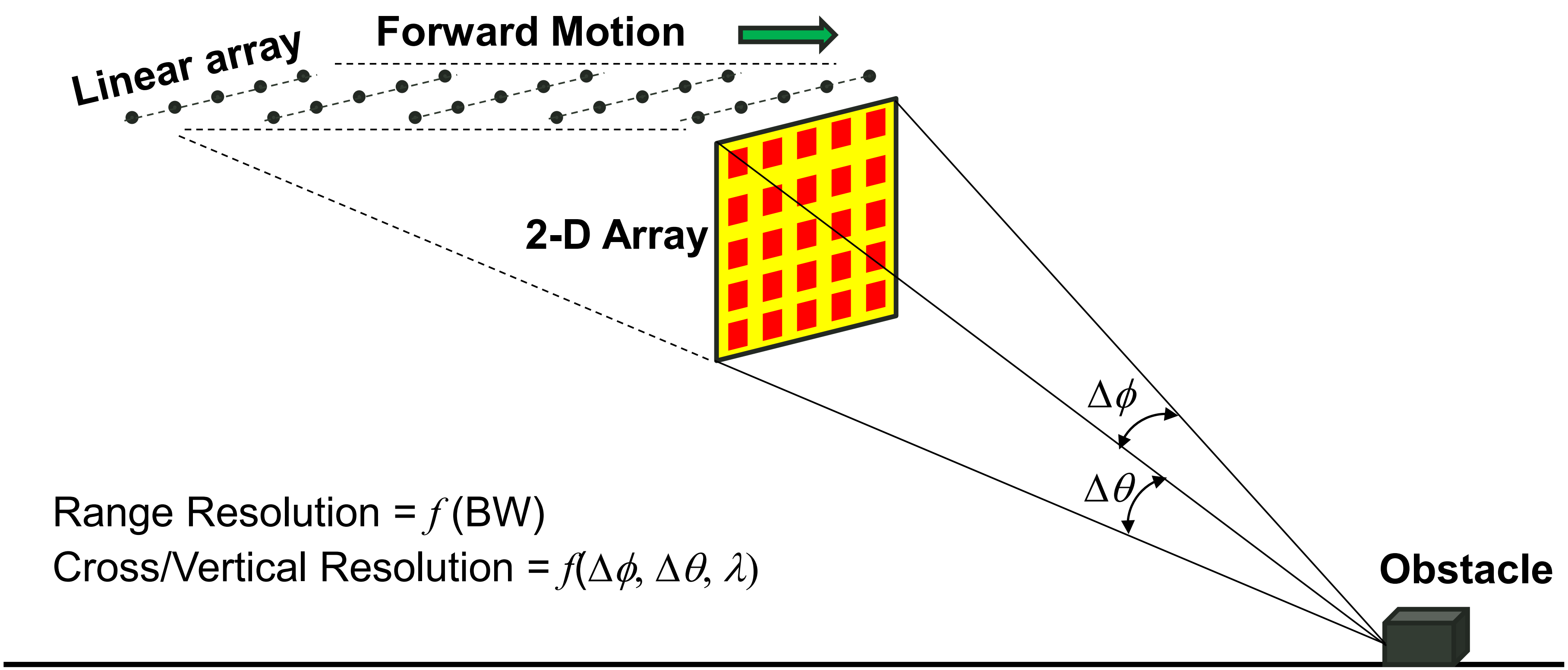
- ARL has been developing ground-based forward looking UWB, low frequency radar technology since 2006
- Multiple concealed target detection applications have been explored (FOPEN, GPEN, STTW)
- The DVE radar operates at longer ranges – higher frequencies required to obtain good cross-range and elevation resolution with the same aperture
- Moving the radar from ground- to airborne platform – new challenges in terms of SWAP, timing, vibrations, positioning information
- While the overall concept is similar, there are some distinct differences:
  - Vastly different operational frequencies
  - 2-D vs. 3-D imaging



DESIGN CONSIDERATIONS

- MMW radar technology offers the following advantages:
  - Good resolution in all dimensions
  - Better penetration (clouds, rain, dust) than IR and optical sensors
  - Low power, small size – especially antenna elements, but also circuitry
- Big technology advances in the commercial world, due to automotive radar and 5-G wireless communications
- Possible choices for frequency band: K (24 GHz), Ka (35 GHz), W (76 and 95 GHz)
- We aim for an image resolution < 0.5 m in all directions
- Estimated average transmitted power on the order of 1–10 W
- Operational range of a few hundred meters from the landing area
- The antenna array size constrained by platform considerations – this limits the achievable cross-range resolution

ANALOGY BETWEEN FLSAR AND 2-D PHASED ARRAY RADAR



Range Resolution = f (BW)

Cross/Vertical Resolution = $f(\Delta\phi, \Delta\theta, \lambda)$

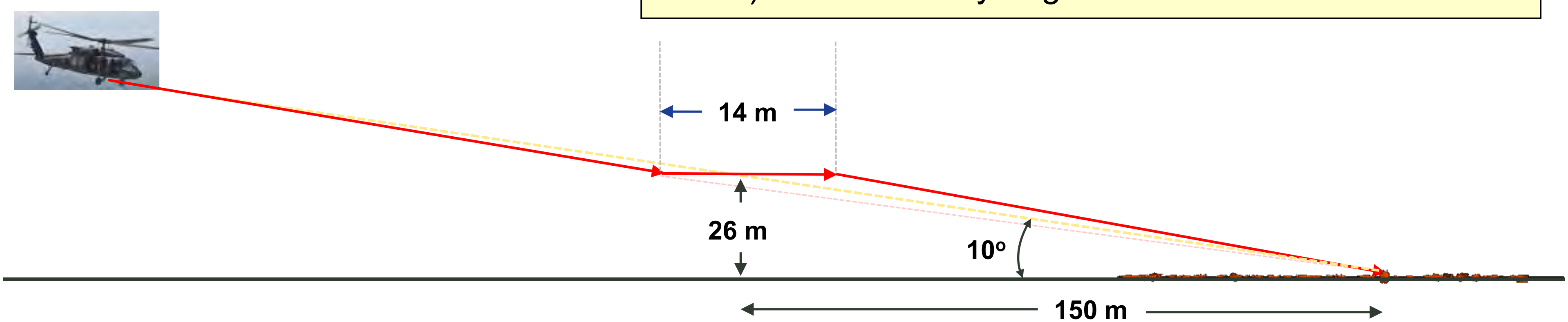
The forward looking linear array combined with forward motion subtends the same angle space as the 2-D phased array radar to achieve comparable resolution. Resolution in the third dimension comes from the signal bandwidth.

SIMULATING A 3-D IMAGE OF LANDING ZONE WITH FLSAR

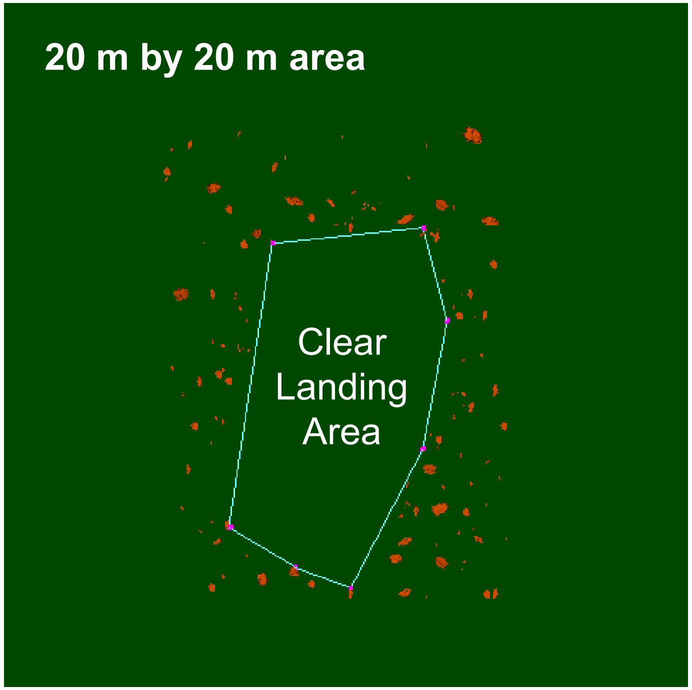
- Helicopter is on a 10º glide path for landing
- To generate resolution in elevation, the glide path is modified to include a 14-m-long level flight section – this allows an elevation angle change of 1º
- 1-m-wide antenna array – 0.4º physical aperture
- We modeled the radar sensing problem using Xpatch, in K-band (24 GHz) and Ka-band (35 GHz)
- Based on the model data, we simulated SAR images at 600 m, 300 m, and 150 m from landing
- Flat surface clear landing area (approximately 5 m by 8 m) surrounded by large rocks

Constant 10º gliding path

Alternate gliding path

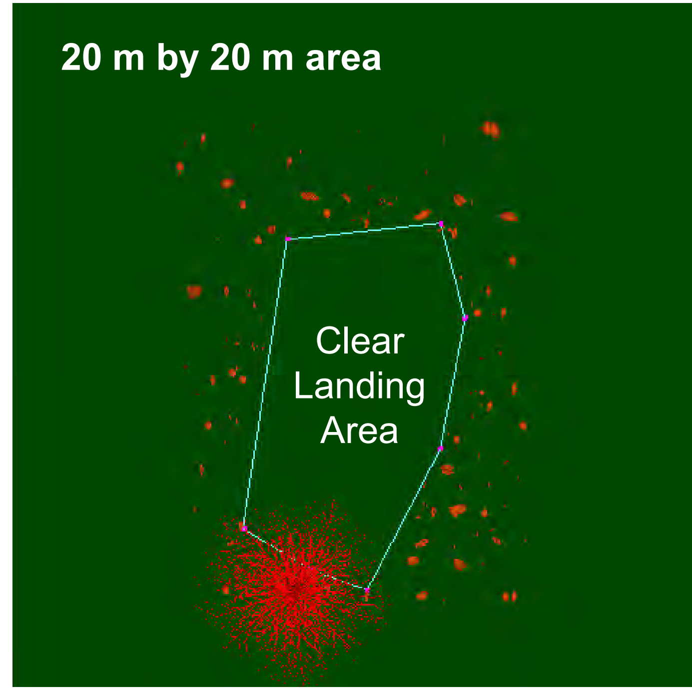


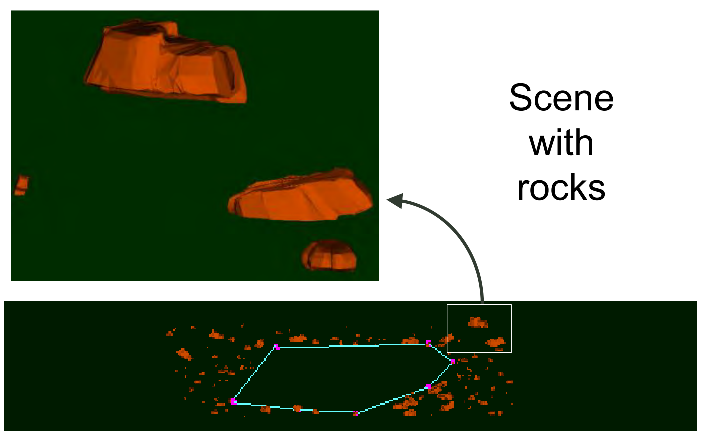
MODELING SCENARIO – LARGE ROCKS AND TREE AS LANDING OBSTACLES



Top View

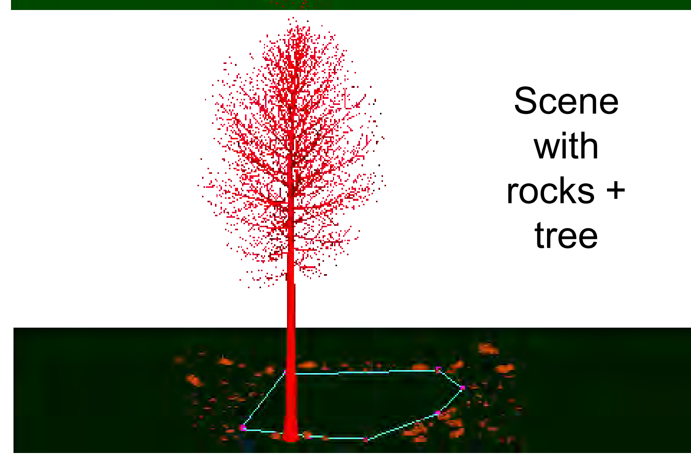
Down-range





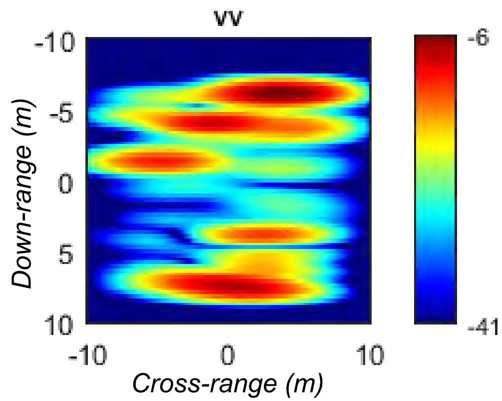
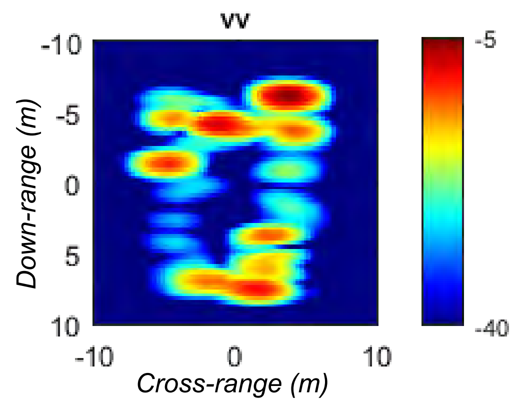
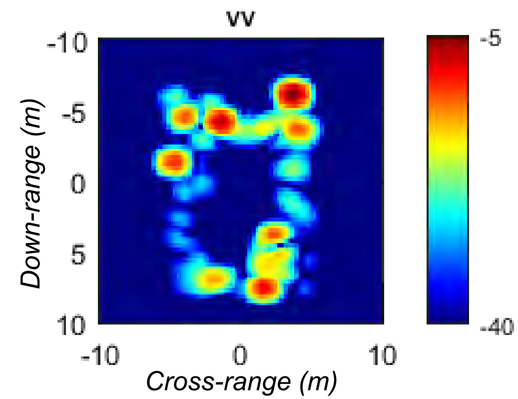
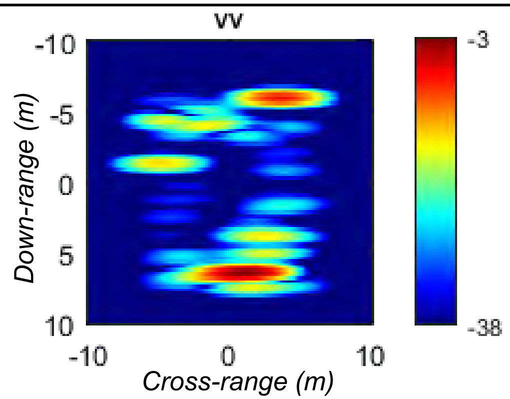
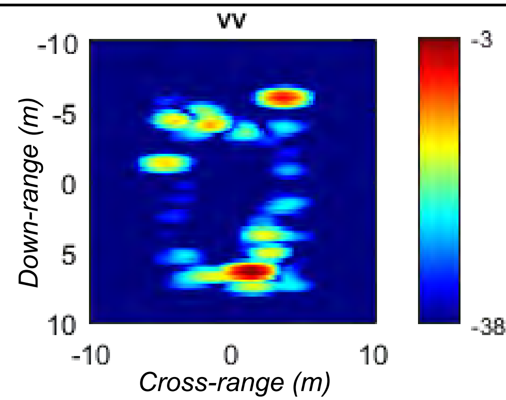
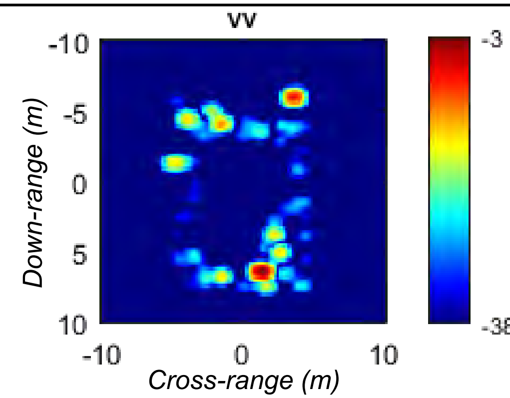
Scene with rocks

Pilot View ($\theta = 10^{\circ}$)



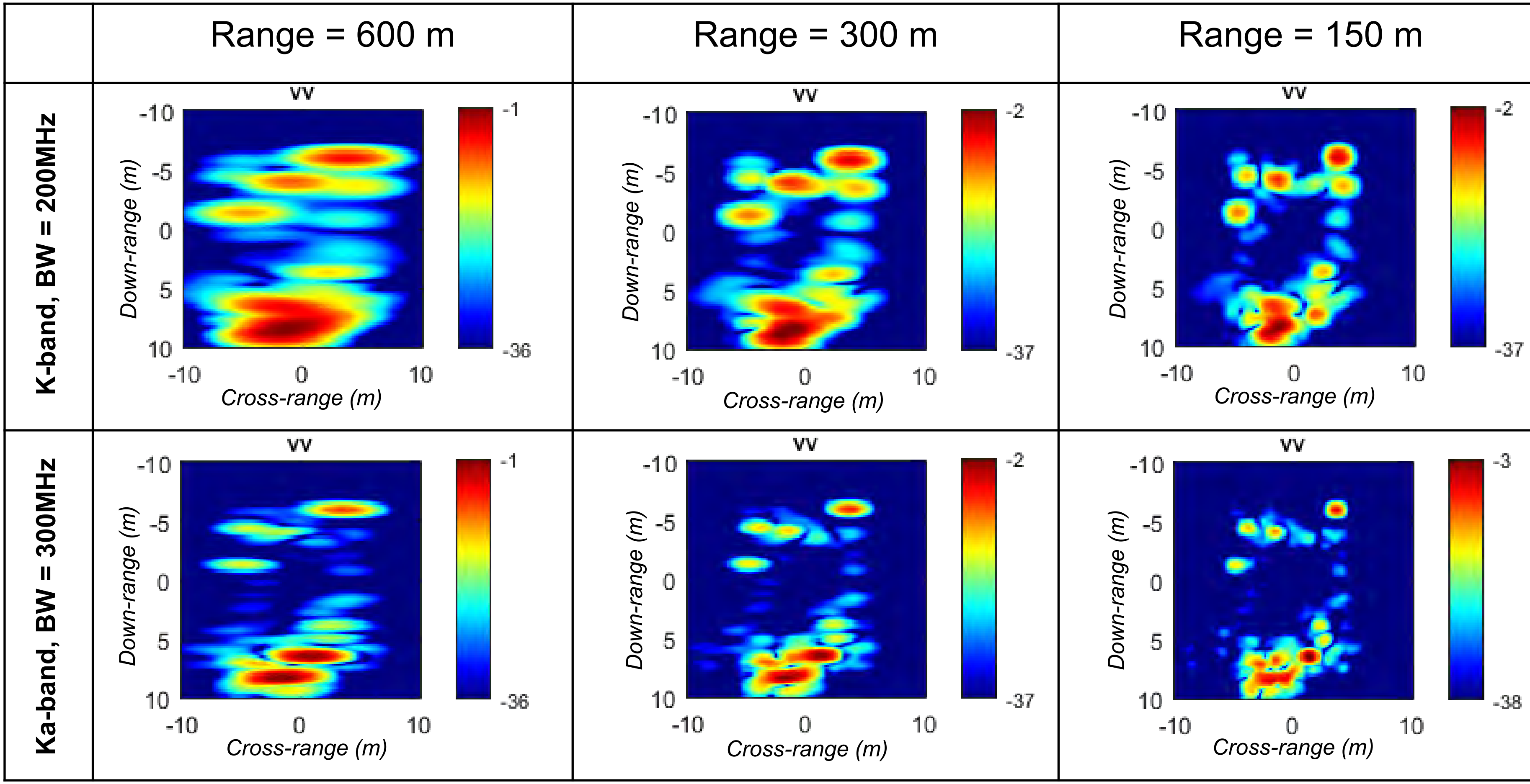
Scene with rocks + tree

2-D SAR IMAGES – GROUND WITH ROCKS

	Range = 600 m	Range = 300 m	Range = 150 m
K-band, BW = 200MHz			
Ka-band, BW = 300MHz			

- These are 2-D ground-plane images obtained at 3 different ranges and 2 frequency bands
- Notice that resolution scales up with frequency
- Cross-range resolution improves at shorter ranges

2-D SAR IMAGES – SCENE WITH TREE

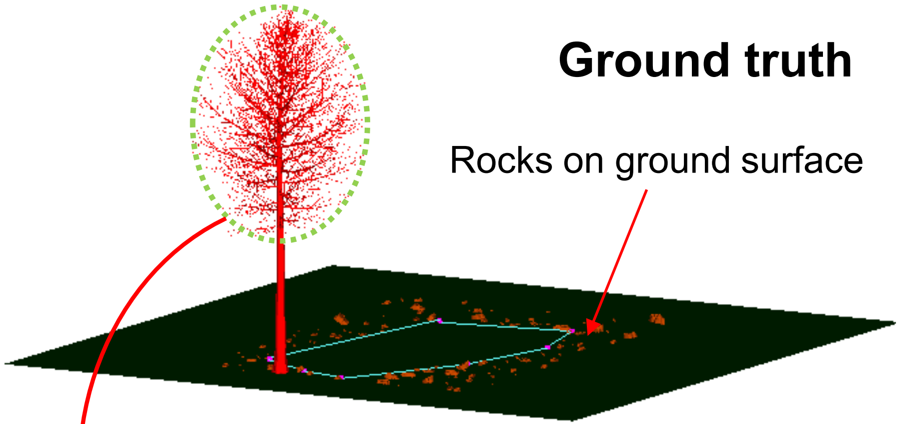


- We cannot identify the tree in the 2-D ground-plane images
- Resolution in elevation (3-D imaging) is required for this purpose

3-D VISUALIZATION OF LANDING ZONE

Ground truth

Rocks on ground surface



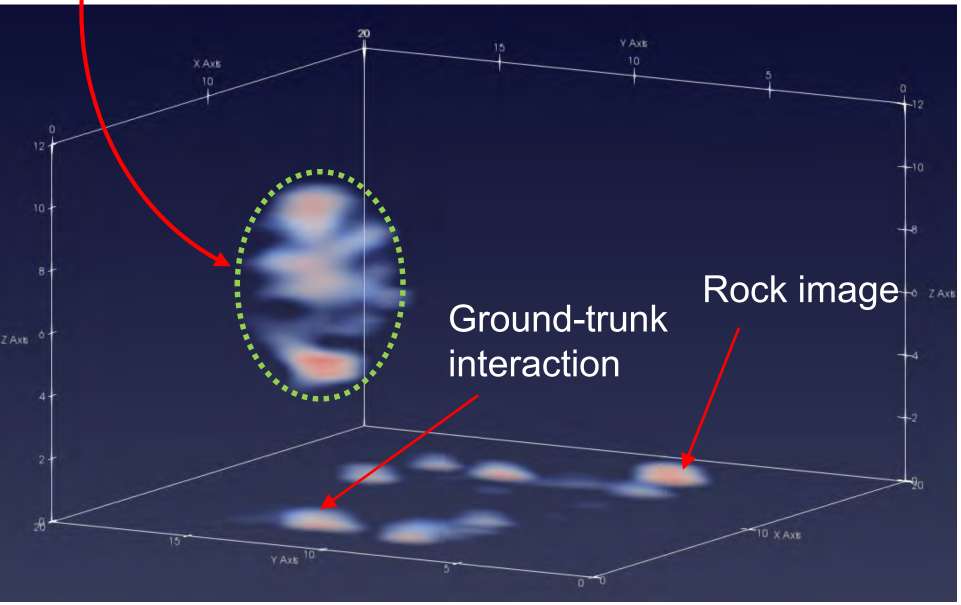
f_c = 24 GHz, BW = 200 MHz

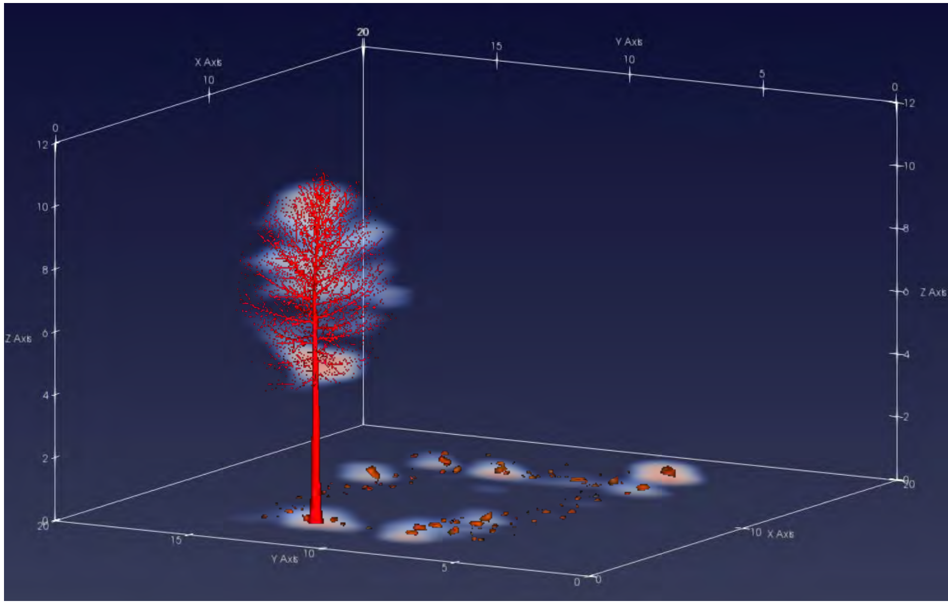
θ = 10°, $\Delta\theta$ = 1°, $\Delta\phi$ = 0.4°

Range = 150 m

25 dB dynamic range

3-D radar image with ground truth overlay

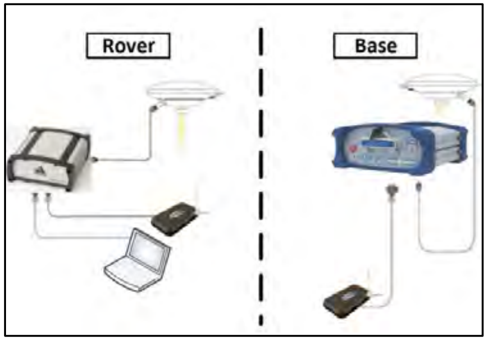


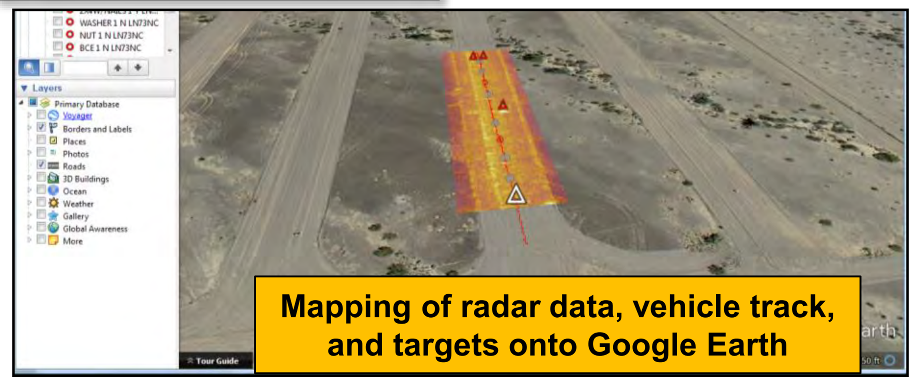


Flying straight and level for a brief period, one can obtain a 3-D terrain map

MOTION COMPENSATION OF SAR IMAGERY

SAFIRE Radar → GPS Hardware





Mapping of radar data, vehicle track, and targets onto Google Earth

For SAFIRE UWB Radar (f = 300 – 2000 MHz), we use Real Time Kinematic (RTK) satellite navigation (with IMU) to improve the precision of position data derived from GPS. Provides overall position accuracy of better than 2 cm. For forward looking DVE SAR, will need an order of magnitude increase in precision.

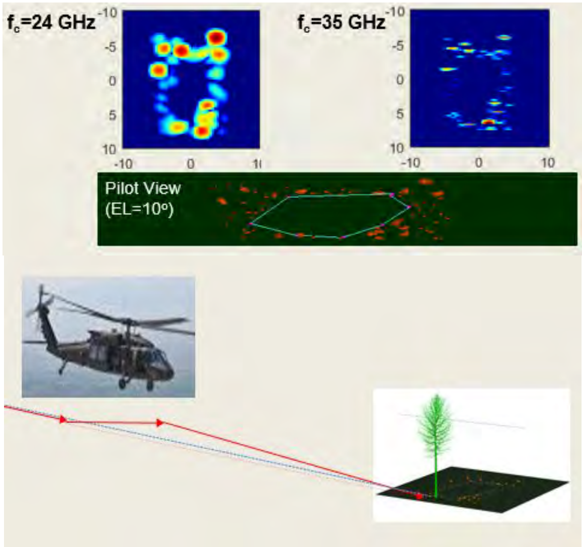
Forward Looking DVE SAR

Potential Solutions:

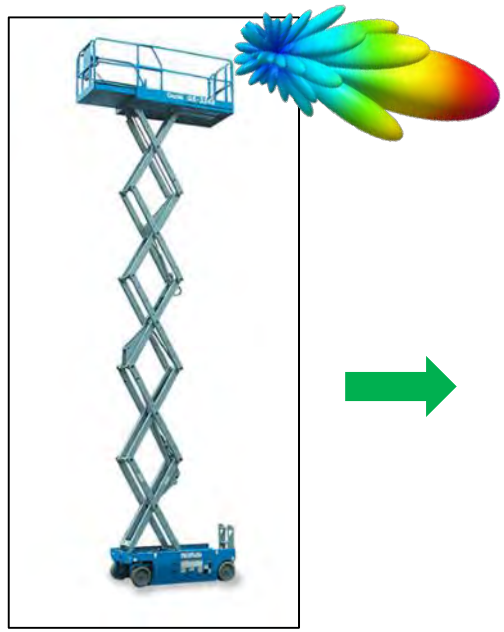
- IMU for coarse correction followed by radar-signal-based correction
- Translational motion compensation
  - Envelope correlation
  - Global range alignment
- Platform vibration compensation and filtering algorithms
- Phase gradient autofocus

An all digital-signal-processing solution may be possible if relative positional accuracy is sufficient, rather than absolute accuracy.

DVE FLSAR MAJOR MILESTONES



Modeling and Simulation
Engineering Trade Space
Hardware Development
FY18-FY20



Ground Demonstration
Post Processing
4QFY20

Airborne Demonstration
on JTARV Platform
Real Time Operation
4QFY22

2018 2019 2020 2021 2022

SUMMARY

- Developing a multi-year research program in FLSAR for DVE
  – Syncs up with CSA priority on Future Vertical Lift, Aircraft Survivability Equipment and Future Unmanned Aerial System S&T demo in 5 years
- The goal is to demonstrate a low-cost radar sensor for 3-D terrain mapping by the end of FY22
- The enabling technologies are mm-wave radar, linear antenna arrays and forward looking SAR
- Our development efforts will be focused on modeling, phenomenology, signal processing and hardware prototyping

Automating Science to Rapidly Discover Higher Performing Armor Ceramics for Readiness Today

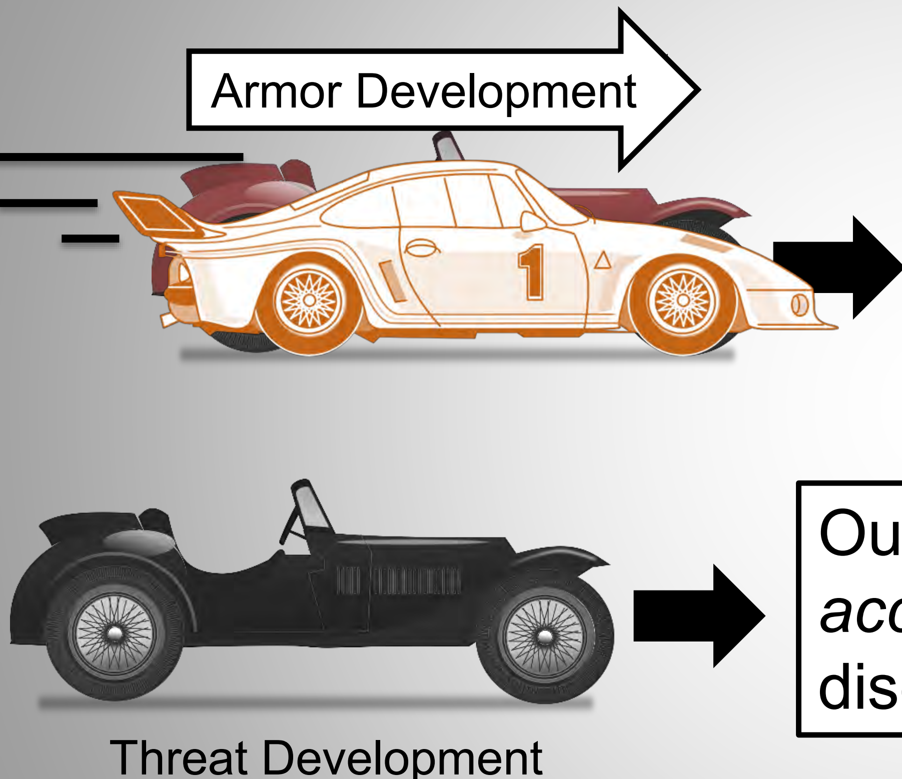
Michael Golt[1], James Campbell[1], Daniel Ashkin[2], Richard Palicka[2]

[1]U.S. Army Research Laboratory, APG, MD.

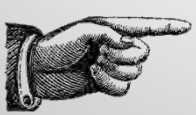
[2]CoorsTek, Vista, CA.

23 AUG 2018

A Solution to the Challenge We Face



Outpace developing threats by *accelerating* the finding of scientific discoveries that lead to better armor.



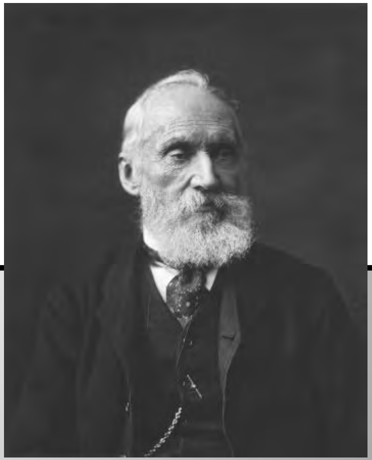
Modernize our approach to science

michael.c.golt.civ@mail.mil

Yesterday's View of Science

"The grandest discoveries of science have been but the rewards of accurate measurement and ***patient long-continued labour*** *in the minute sifting of numerical results."*

– Lord Kelvin (1883)



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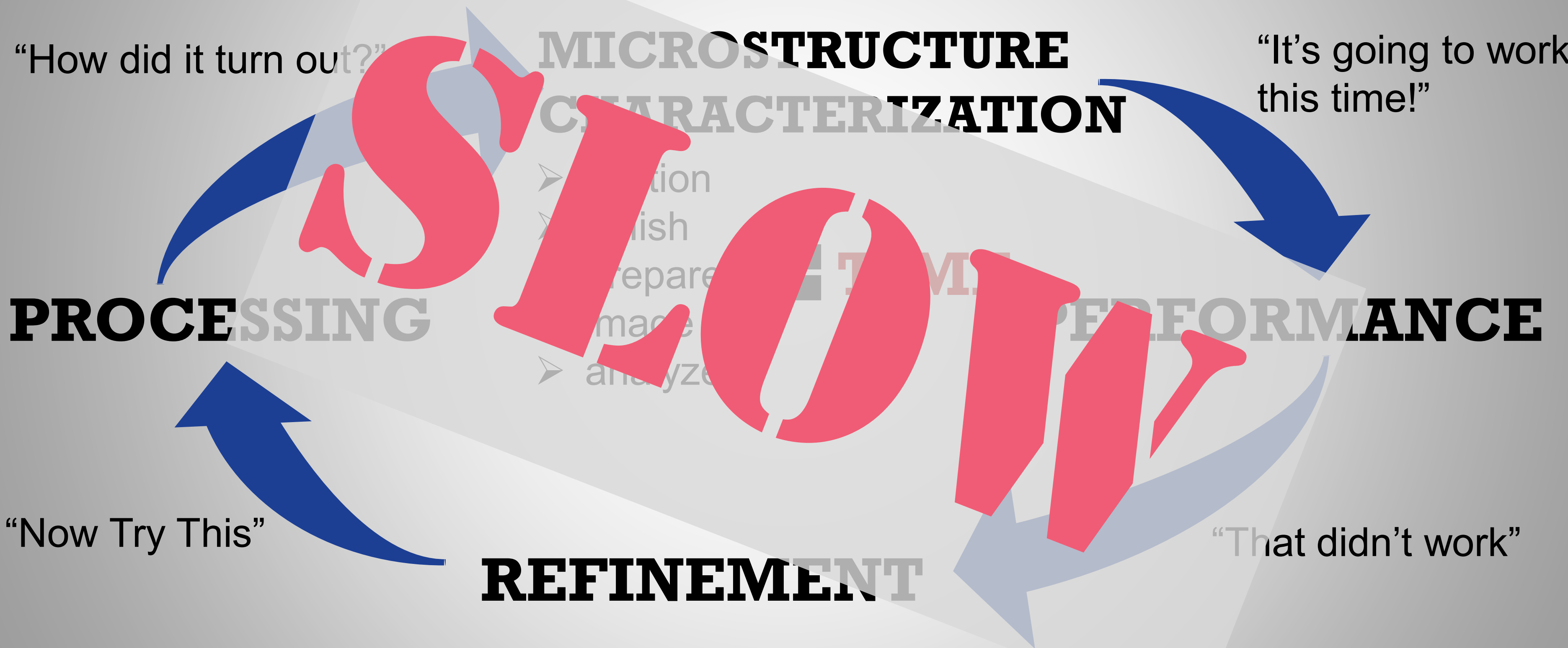
Overcoming the Rate Limitations

NEED TO KNOW: Processing → Structure → Performance

Traditional approach to materials discovery



RESULT: Tired, inefficient material discovery and development, (10’s of samples)

michael.c.golt.civ@mail.mil

eed

RESULT: Stre ... development,

PROCESSIN ... FORMANCE TESTING

Results:
A B C : X
A B D : X
D B C : ✓

High-Throughput Experimentation (HTE)

High-Throughput Screening Example

Robots used to rapidly screen millions of drug compound combinations

Photo top: Maggie Bartlett, NHGRI (Wikimedia)
Photo bottom: Chris Frazee, UW-Madison HTS

High-throughput screening **drives** early-stage drug discovery.

“Big rewards to quickly finding a life-saving drug”

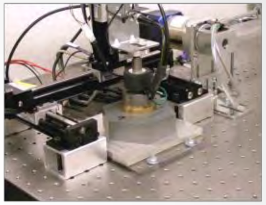
michael.c.golt.civ@mail.mil

Our Modern Approach to Discovery

High-throughput Experimentation

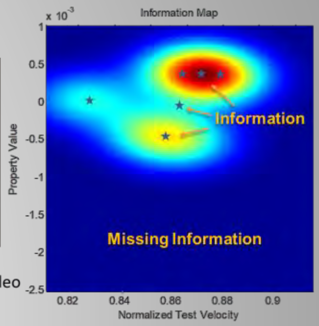
1 Combinatorial, High-Volume Ceramic Processing

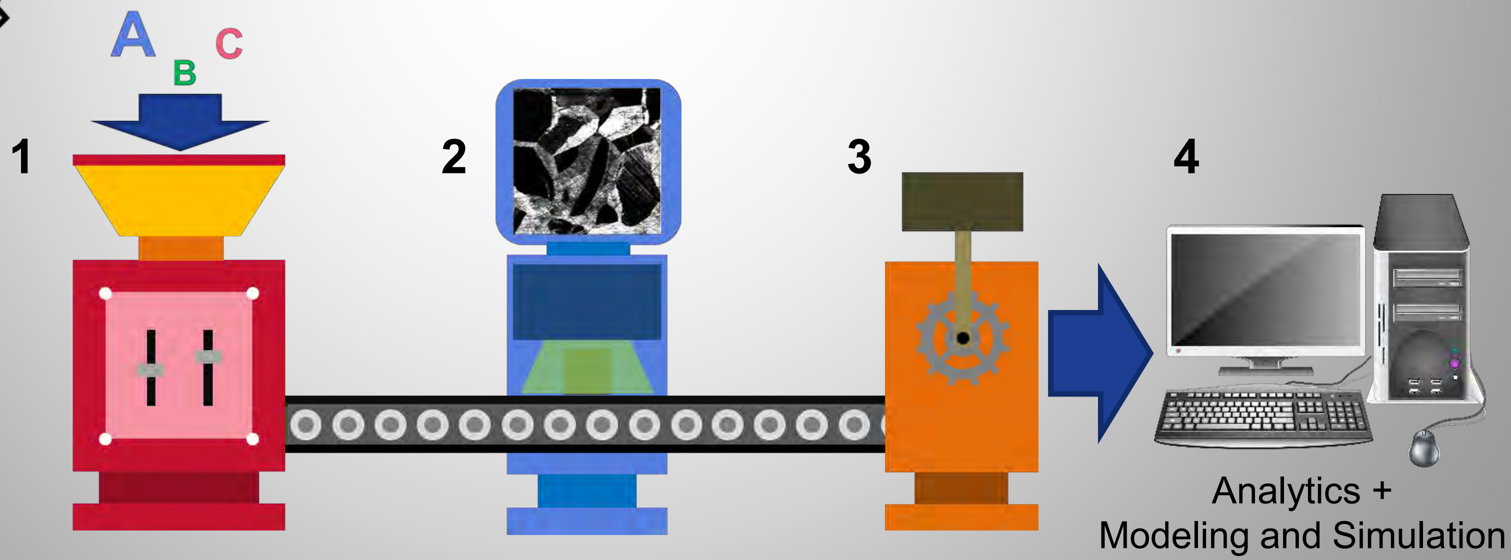
2 High-Throughput Microstructure Characterization using Electric Fields



3 Intelligent Ballistic Testing

Comprehensive projectile characterization, high-speed video determination of pitch/yaw





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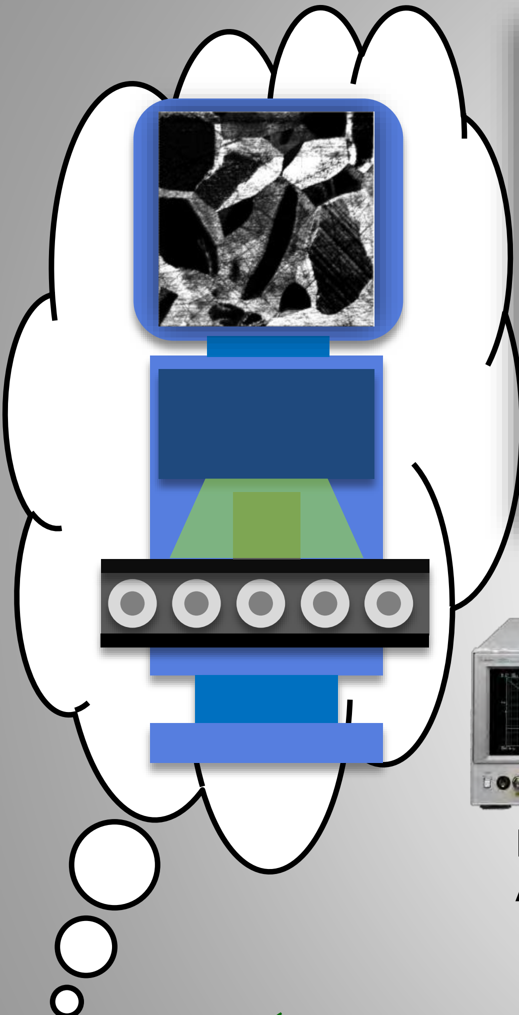
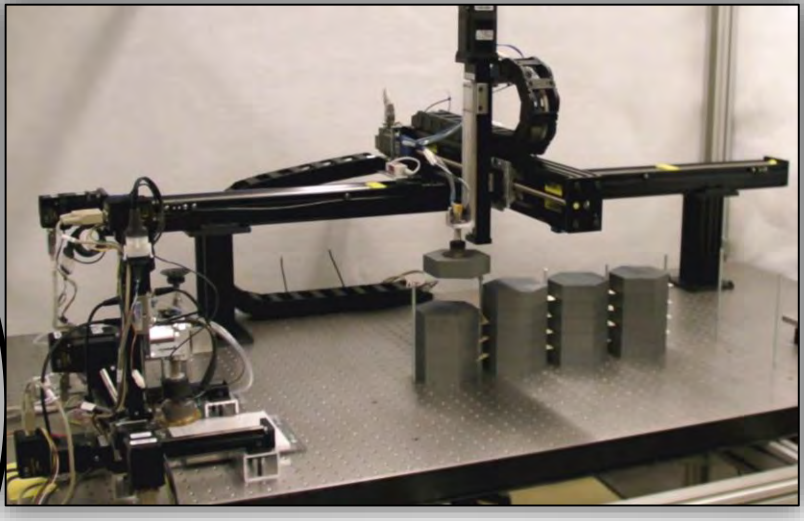
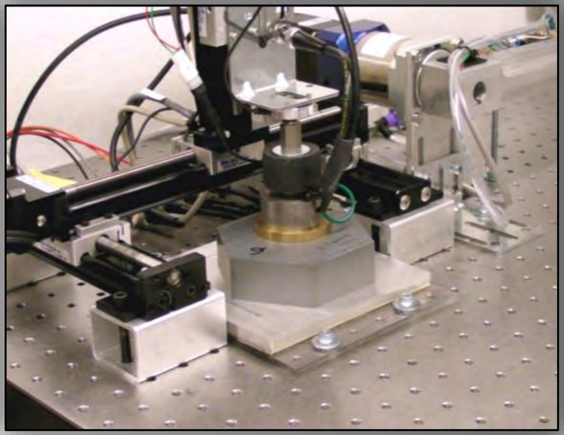
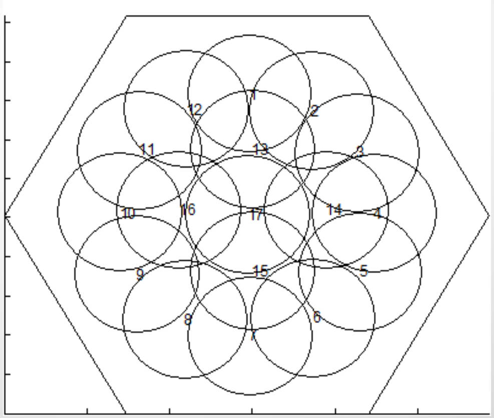
High-Throughput Armor Characterization

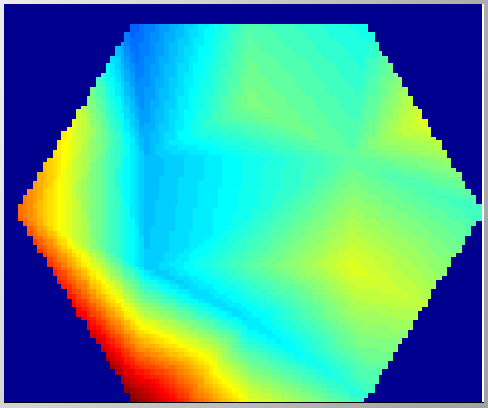






Impedance Analyzer





- ✓ **Fast and Non-Destructive**
- ✓ **100's of samples measured at a time**

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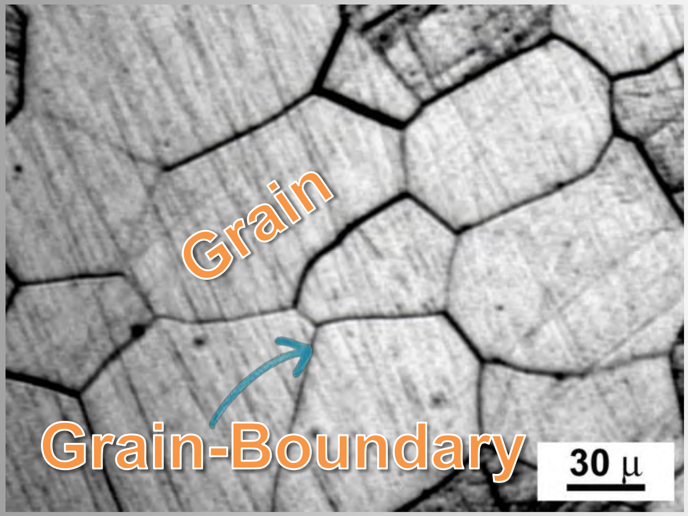
How it Works

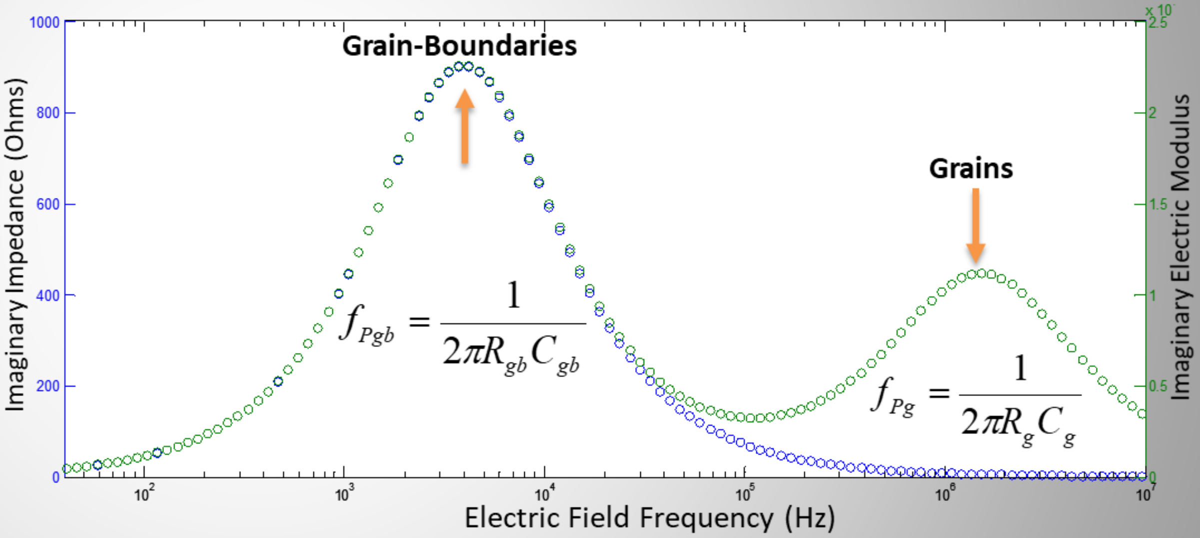
Goal: Link armor structures to processing and performance

Microstructure



Wikimedia commons

Impedance Spectrum Analysis



Electrical measurements tell us A LOT about the structure

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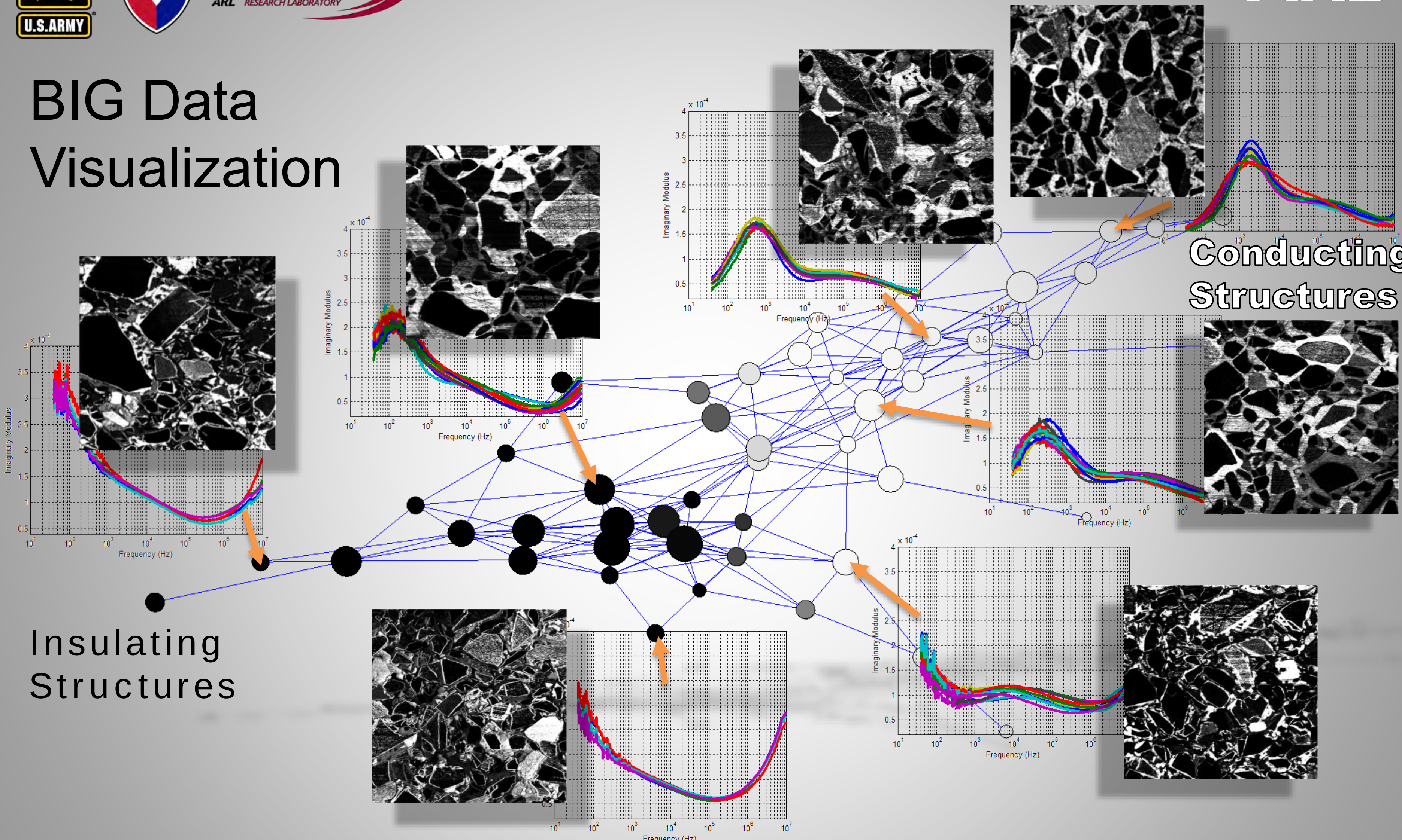
So Much Information!

BIG Data Visualization



Making links between Processing→Structure→Performance

Golt, M. C., et al. J. Appl. Phys. **120**, 024302 (2016);

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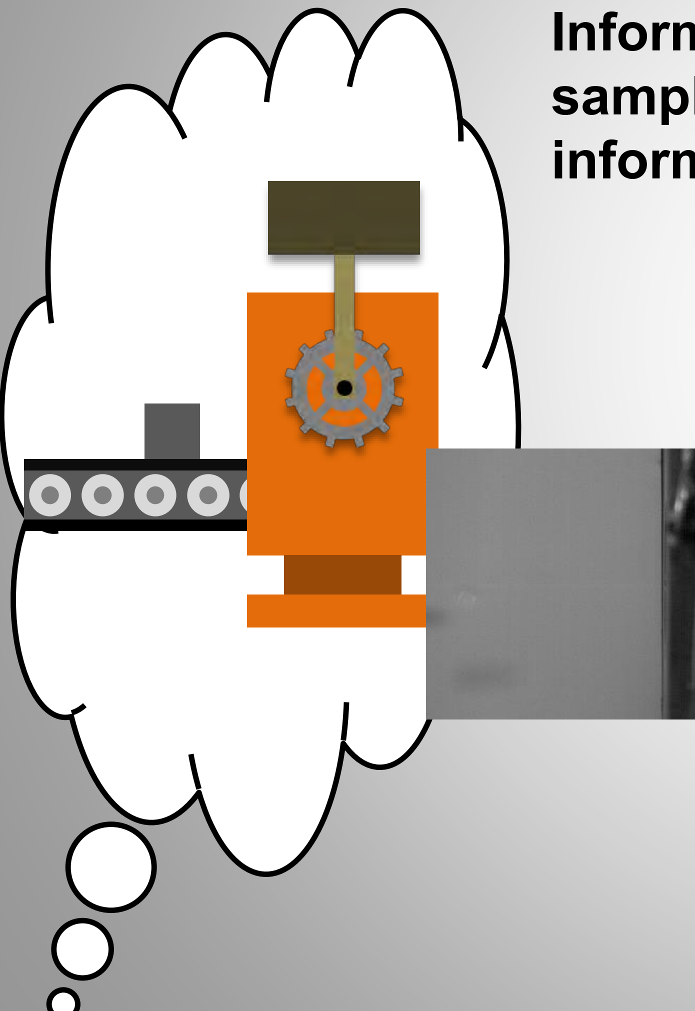
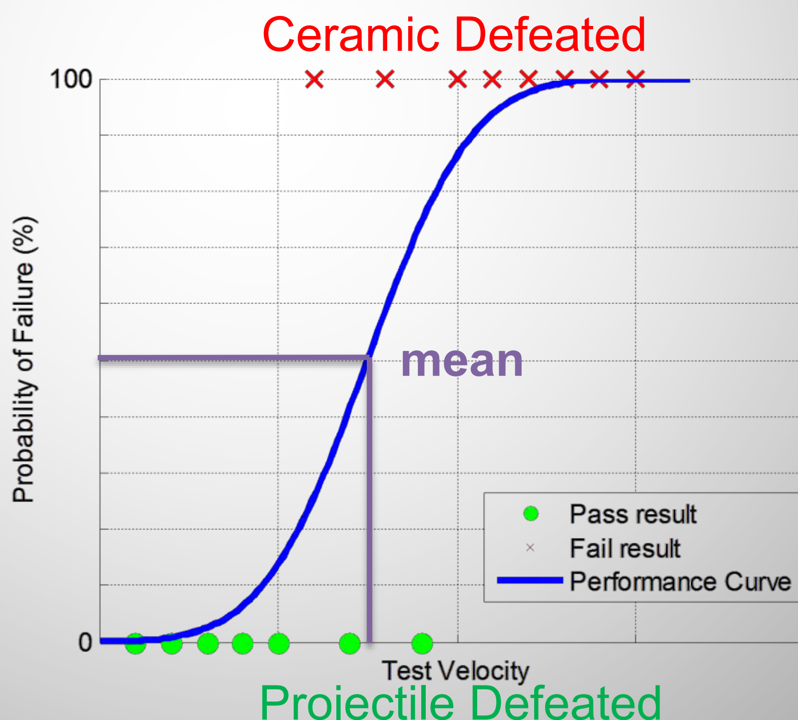
A Better Way to Test Performance

How to *efficiently* evaluate the structure's performance?



Information-based testing used to determine the sample order and projectile velocity that MAXIMIZES information.



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Best Performing Structures Discovered!

Now we know WHAT is the better armor

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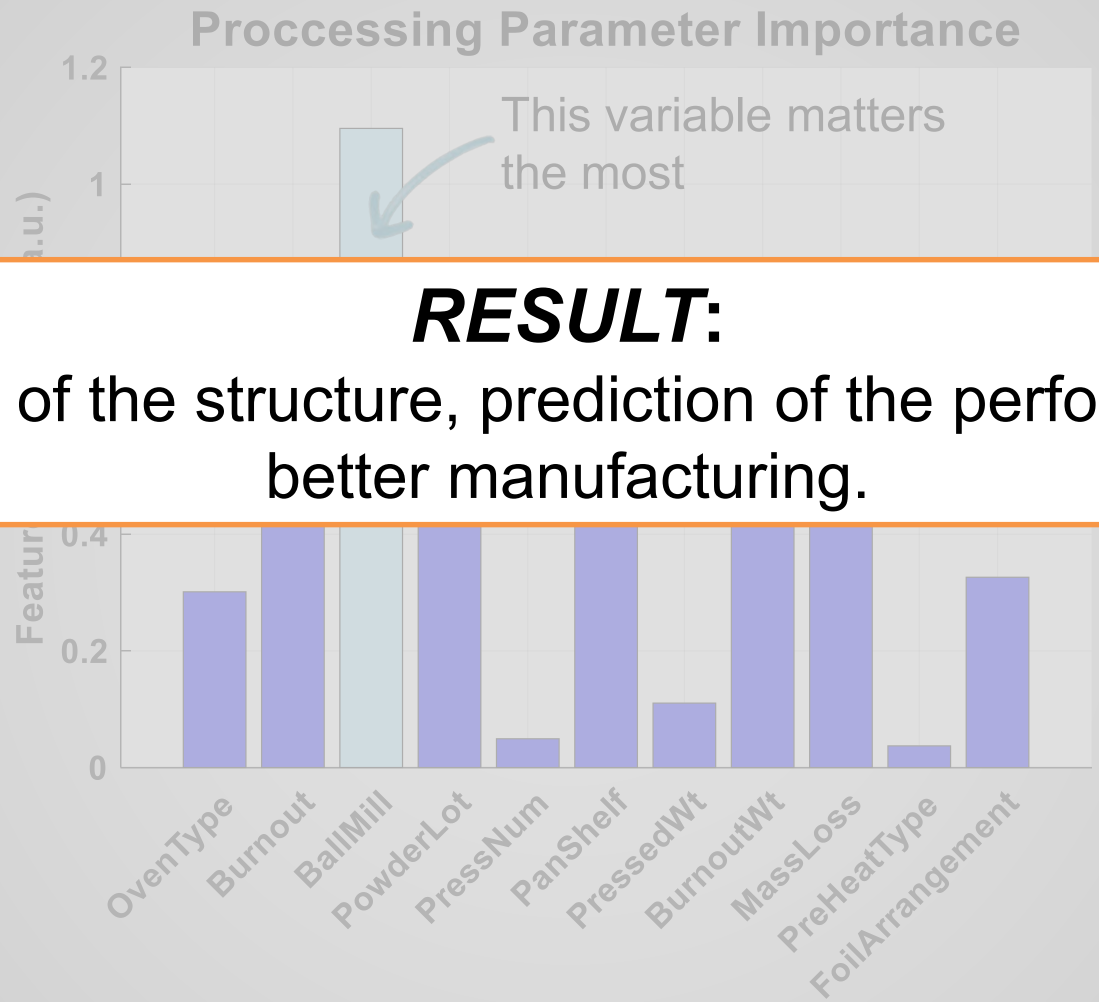
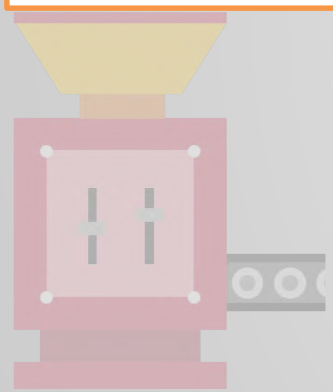
Best Processing Controls Discovered!





***RESULT*:**
Knowledge of the structure, prediction of the performance, and better manufacturing.

Now we know HOW to make better armor

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A Fast-Paced Future for Science

In the future,

science is automated and discoveries are abundant.†

Science of the Past

Discovery

goldrushtradingpost.com

The Future of Science

Discoveries!

alluvialgoldmachine.com

†Golt, M. *Increase the Impact and Abundance of Discoveries, Innovations, and Transitions by Automating Science*. U.S. Army Research Laboratory Special Report, ARL-SR-0400, July 2018.

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Extrusion Based Additively Printed Magnets Outperforming Traditional Injection Molded Magnets

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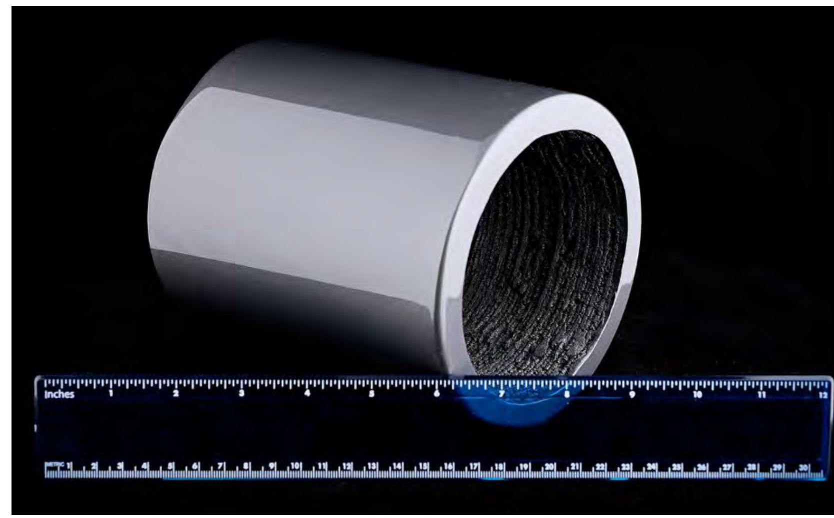

This work was supported by the Critical Materials Institute, an Energy Innovation Hub funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office

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National Laboratory

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Ikenna Nlebedim, Helena Khazdozian, Kinjal Gandha, Tom Lograsso **(Ames)**
Scott McCall **(LLNL)**

Jim Herchenroeder **(Neo Magnequench)**
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John Ormerod, Robert Fredette **(Magnet Applications Inc.)**
Aaron Williams **(Arnold Magnetic Tech.)**
Zaffir Chaudhry, Jagadeesh K. Tangudu **(UTRC)**
Rick Spears **(Tru-design Inc.)**
Preston Bryant **(Momentum Technologies)**

Rare Earth Permanent Magnet Applications

- PM are widely used in automobiles, hard disk drives, motors, sensors, wind power generators, transducers, loudspeakers, etc.

Critical Rare Earths	Rare Earth Magnets	Automobiles
Permanent Magnets Nd (Dy)-Fe-B Sm-Co Global production: 140 tons (2020) Global market: $ 1-2 Billion	Permanent Magnets Nd (Dy)-Fe-B Sm-Co Global market: $ 41.41 Billion (2022) $ 21 Billion (2016) (62% NdFeB)	More than 25+ types of magnets used; Electric and hybrid cars contain 20-25 lbs. of rare earths. Global market: $ 1.7 Trillion (2015)

Present: 90% rare earth world supply – China

10 million tons of RE needed for 2050 (Prof. M. Sagawa)

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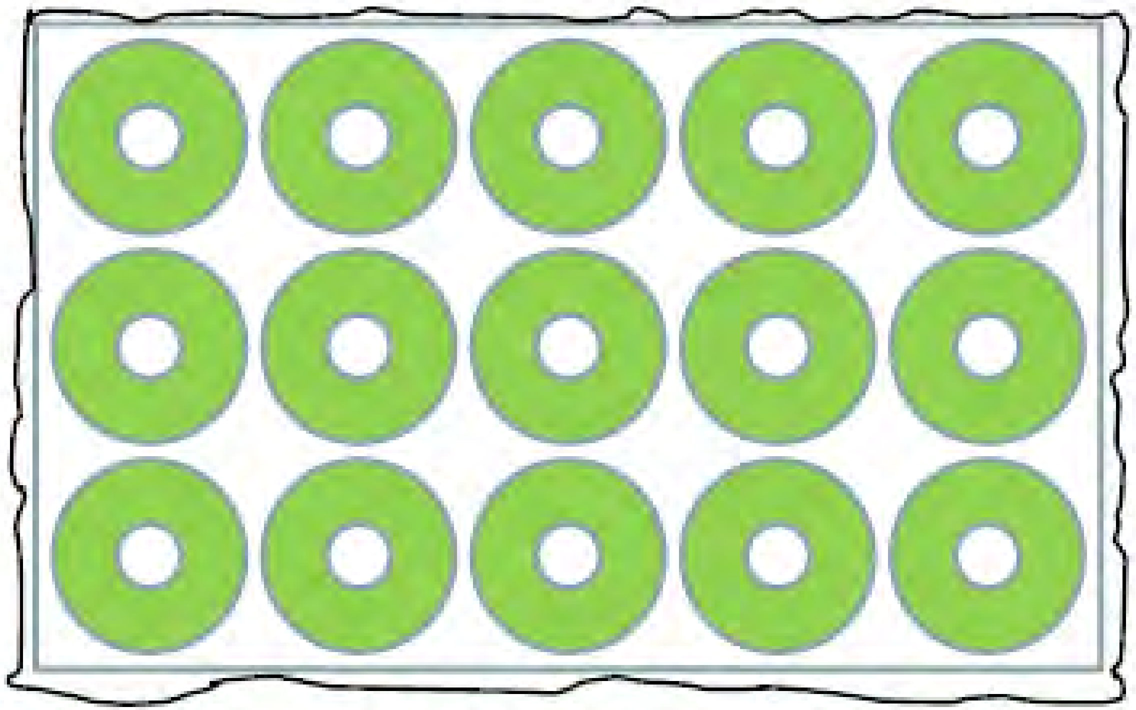
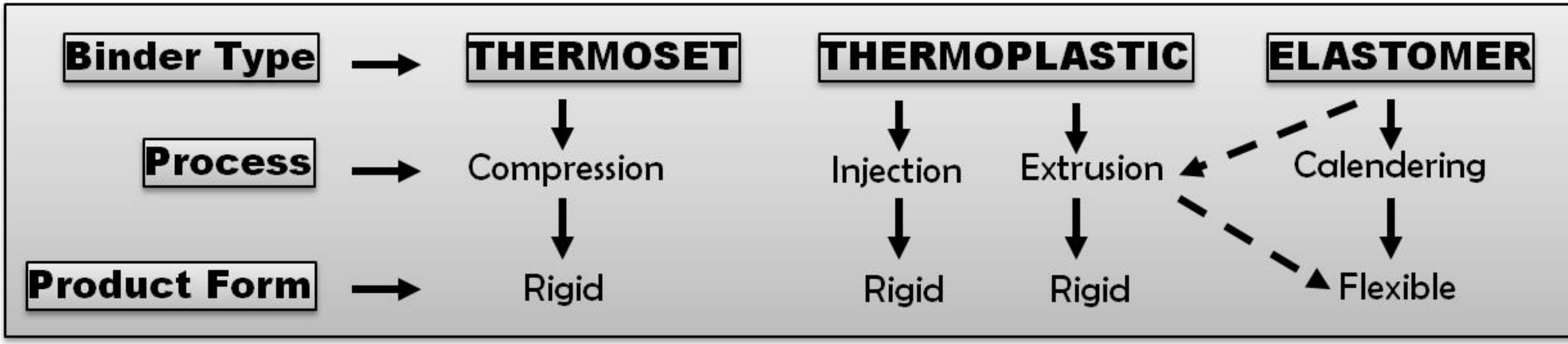
Sintered Magnets – Materials Yield Low



Cored Centers
Utilization – 52%

Bonded Magnets



Processing Type	Vol. Fraction	Br	(BH)max
	Loading	% of sintered alloy	% of sintered alloy
Explosive compaction	81%	81%	65.6%
Compression Bonded	79%	79%	62.4%
Extruded	75%	75%	56.3%
Injection molded, polyamide	65%	65%	42.3%
Injection molded, PPS	61%	61%	37.2%

$\boxed{(BH)_{max} \sim f^2}$

Source: Ormerod, J. & Constantinides, S., J. Appl. Phys. 81, 4816–4820 (1997)

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Injection Molded Magnets

Magnetic Materials

- Ferrites
- Nd-Fe-B
- Blends of magnetic materials (Nd-Fe-B; SmFeN)

Binder Types

- Nylon 6 and 12
- PPS (Polyphenylene sulfide)
- Polyamide

Advantages/Disadvantages

- Simple or complex shapes
- Operating temperatures: -40 °C to >180 °C
- No post-finishing is required
- Magnet loading: ~ 65 vol %;
  BH_{max} (injection) < BH_{max} (compression)
- Anisotropic or isotropic – wide range of magnetic alignment possible
- High tooling costs: high volume manufacturing
- Mechanical properties: > sintered magnets

Compression Bonded Magnets

Magnetic Materials

- Nd-Fe-B
- SmCo
- Different grades of materials

Binder Types (thermoset)

- Epoxy (compatible with solvents and automotive fluids)

Advantages/Disadvantages

- Simple shapes (cylinder, rectangular, arc)
- Operating temperatures: -40 °C to >165 °C
- Magnet loading: ~ 80 vol %; BH_{max} (compression) > BH_{max} (injection); but < BH_{max} (sintered)
- Low tooling costs: modest volume manufacturing
- Coated with epoxy to reduce corrosion after shaping
- Mechanical properties: > sintered magnets

Good characteristics of a magnet

- Flux density (B_r); Energy Product (BH_{max})
- Resistance to demagnetization (Hcj)
- Usable temperature range; Magnetization change with temperature (RTC)

- Demagnetization (2nd quadrant) Normal curve shape
- Recoil permeability
- Corrosion resistance; Physical strength

- Electrical resistivity' Magnetizing field requirement
- Available sizes, shapes, and manufacturability
- Material availability and product cost

Physical Properties	Sintered NdFeB	Compression Bonded NdFeB	Injection Molded Bonded NdFeB
Density	7.5-7.8 g/cm³	5.6-6.0	4.5-5.5
Compressive Strength	850-1050 MPa	80-120	--
Young's Modulus	150-160 GPa	0.7-1.0	--
Tensile Strength	--	37	25-40
Electrical Resistivity	1.2-1.6 μΩm	10-30	40-70
Specific Heat	440 J/(Kg.°C)	400	--
Thermal Conductivity	9 W/(mK)	2	

Source: Steve Constantinides, Arnold Magnetic Technologies

BONDED MAGNETS – Additive Printing

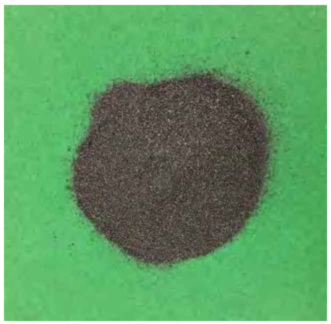
- **Goal:** To fabricate near-net shape NdFeB magnets and to minimize the generated waste associated with magnet manufacturing and reduce the overall cost.

  - One of the ways in which we can achieve this goal is by using additive manufacturing (AM) techniques to create complex shapes and geometries of bonded magnets from a computer aided design which requires little or no tooling and post-processing thus reducing the amount of waste generated.
  - Rapid prototyping: Reduced time to market for new magnet/motor designers.

Magnet Powders: Magnequench MQP and MQA NdFeB (Iso and Anisotropic); Aichi-Steel Dy-free NdFeB Magfine; Sm-Co; SmFeN
Polymers: Nylon; PPS

Schematic Illustration of the BAAM Process

MQP isotropic powder



+

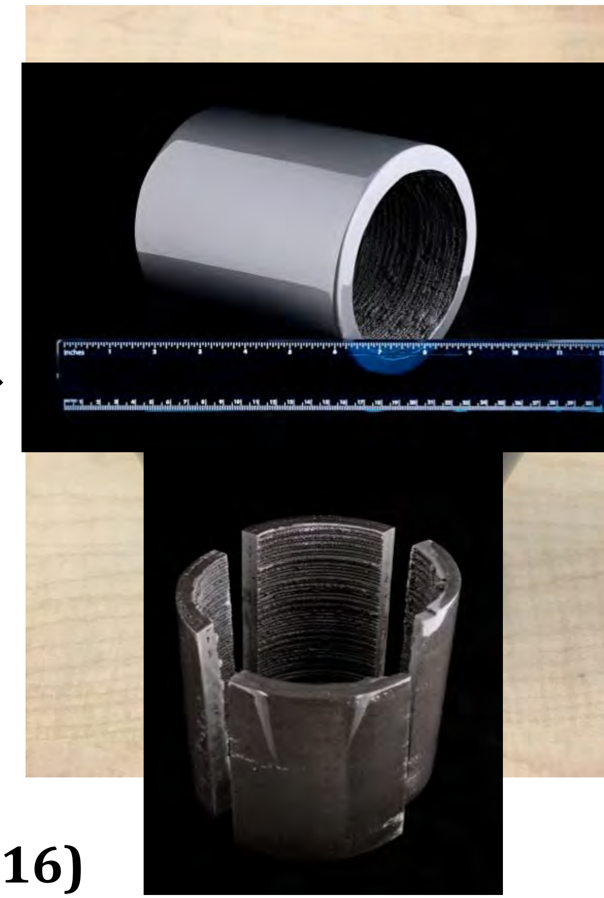
Nylon-12

Mix, melt and extrude

Composite pellets:
65 vol % MQP+ Nylon

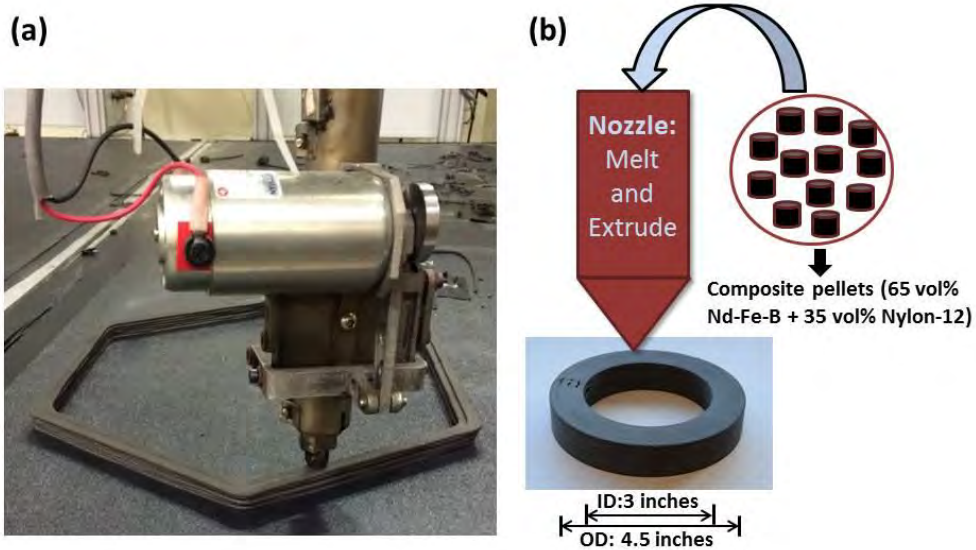
BAAM 3D printing

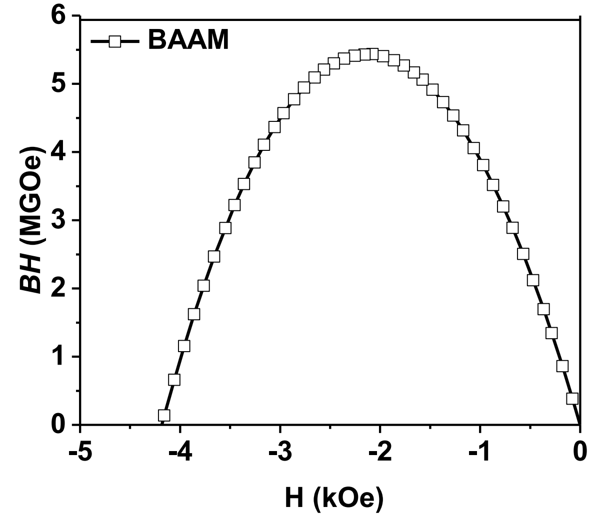
Additively printed NdFeB bonded magnets

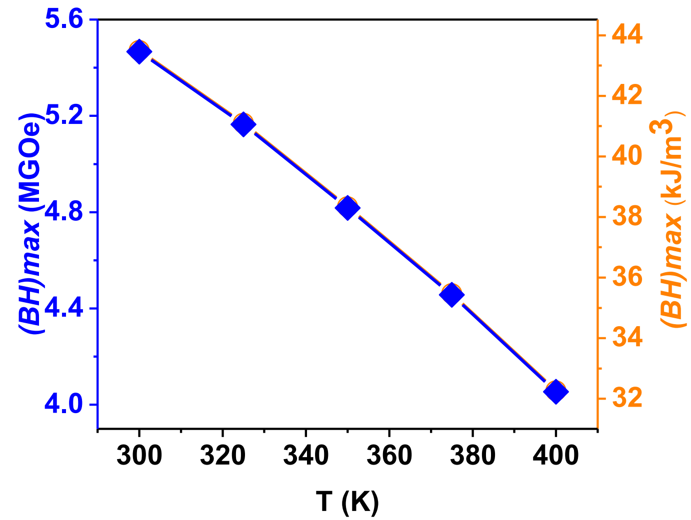


Li, L. *et al.*, *Sci. Rep.* 6, 36212 (2016)
Magnetic Moments, The Economist, Nov. 19, 2016

Big Area Additive Manufacturing (BAAM) of Isotropic NdFeB Nylon Bonded Magnets



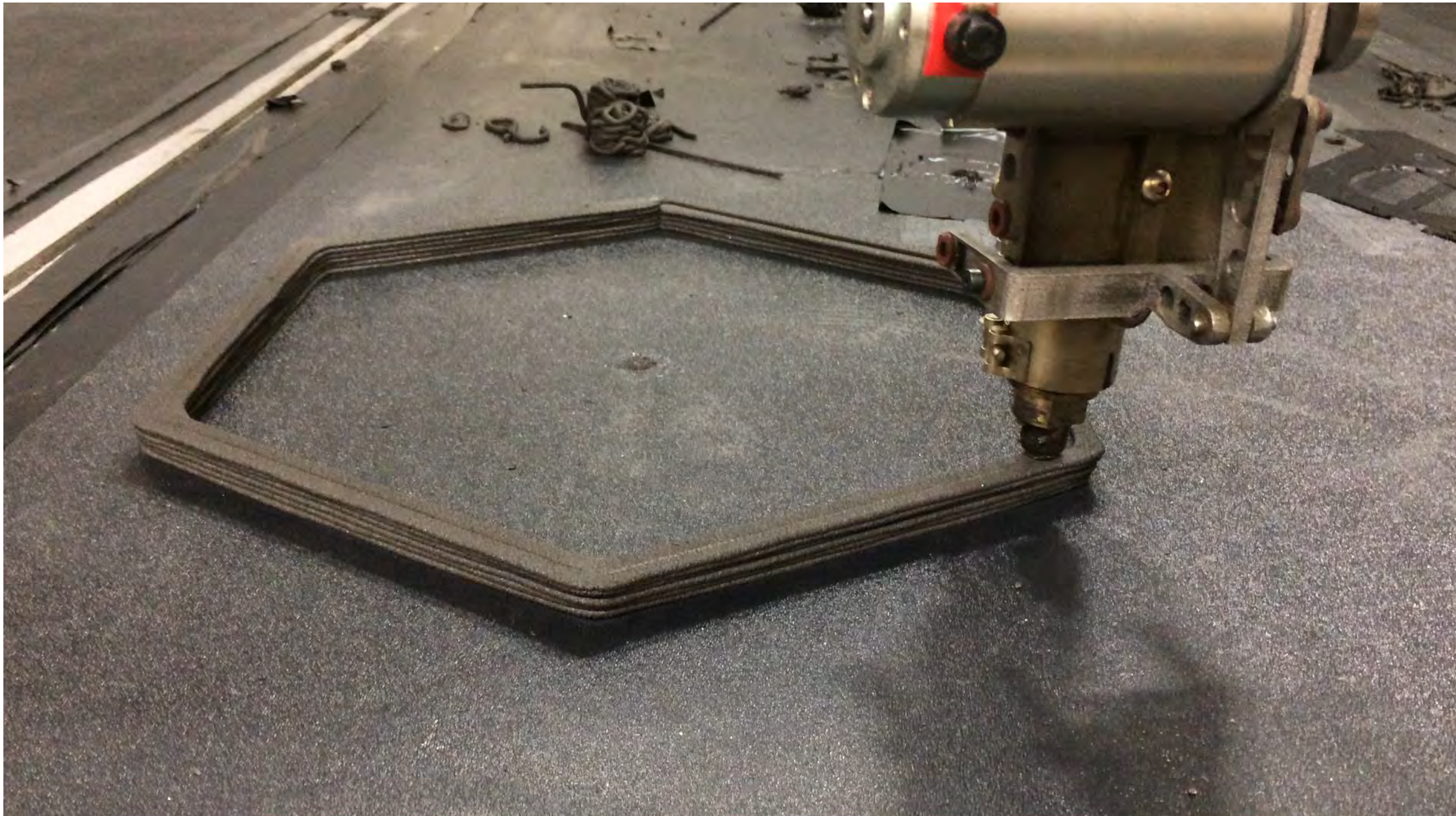




Why AM?

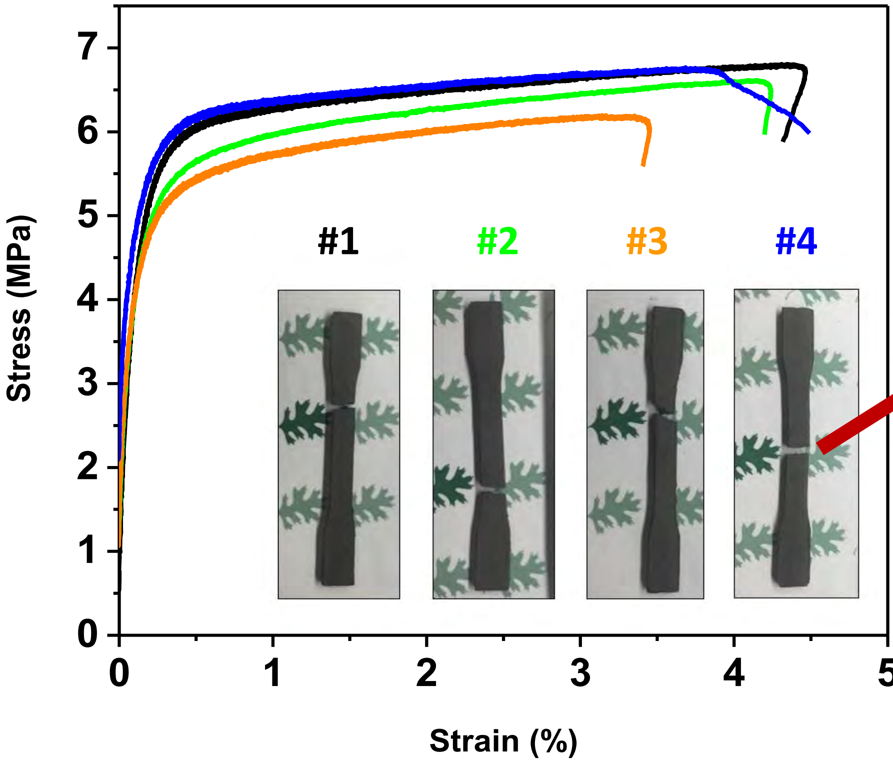
- No tooling required, cost effective
- Minimum critical material (rare earth) waste
- Rapid prototyping
- No limitation in sizes and shapes
- (BH)max = 5.31 MGOe; Density = 4.9 g/cm^3

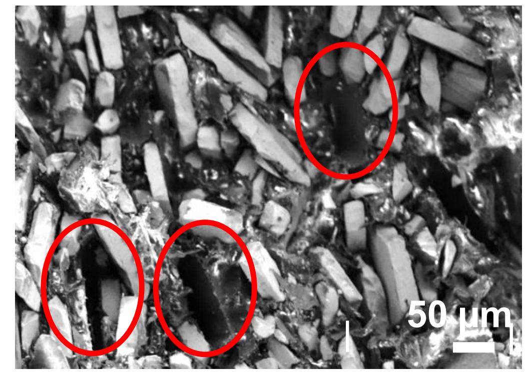
Big Area Additive Manufacturing (BAAM)



Source: Ling Li, Angelica Tirado, I.C. Nlebedim, Orlando Rios, Brian Post, Vlastimil Kun, R.R. Lowden, Edgar Lara-Curzio, Robert Fredette, John Ormerod, Thomas A. Lograsso, and M. Parans Paranthaman, "Big Area Additive Manufacturing of High Performance Bonded NdFeB Magnets," *Nature: Scientific Reports* (2016).

BAAM magnets – Mechanical properties





Fracture is primarily related to the debonding of the magnetic particles from the binder.

Young's Modulus (GPa)	Ultimate Tensile Strength (MPa)	Ultimate Tensile Strain
4.29	6.6	4.18%

Critical Materials Institute
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Li, L. *et al., Sci. Rep.* **6**, 36212 (2016)

OAK RIDGE National Laboratory

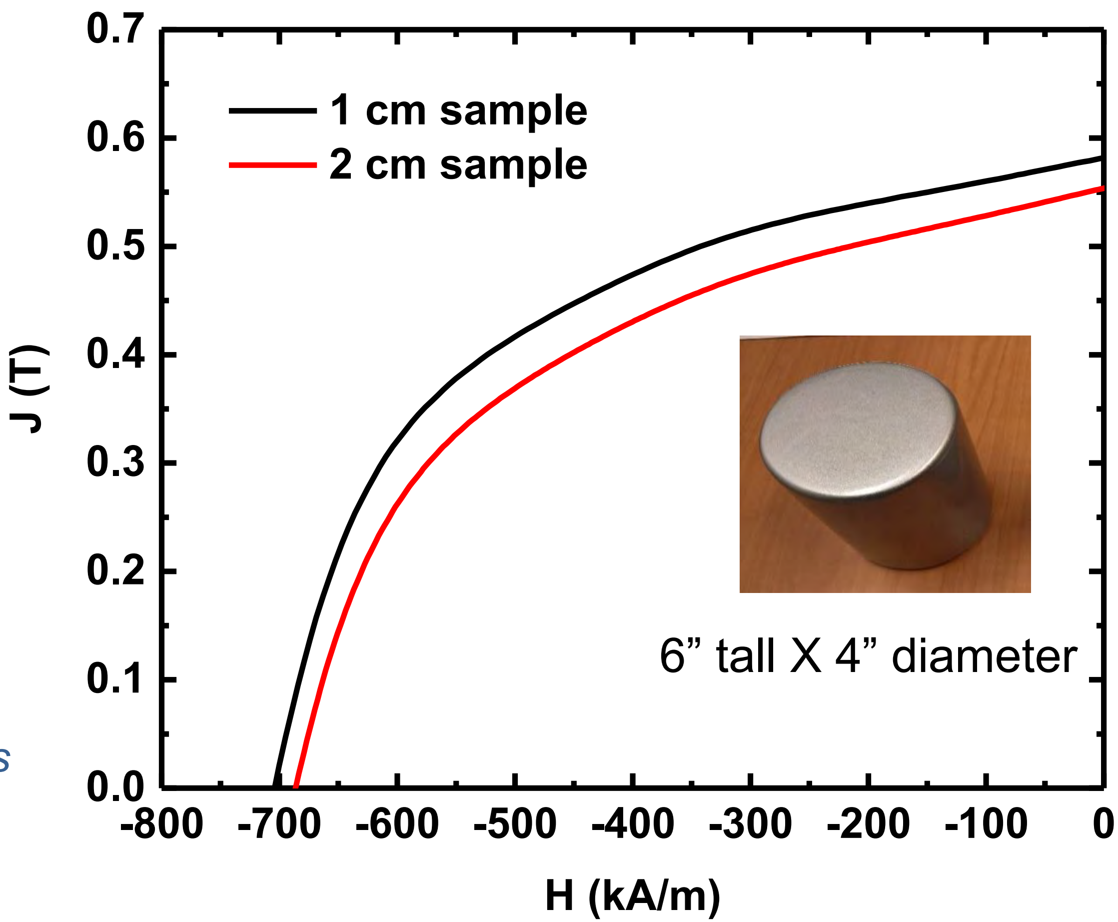
BAAM Magnets Outperformed Injection Molded Magnets with High Magnet Loading in a Polymer

Achievement:

Big Area Additively Manufactured (BAAM) NdFeB bonded magnets with 70 vol % magnets compared to 65 vol % magnets using traditional injection molding in nylon.

Research Details:

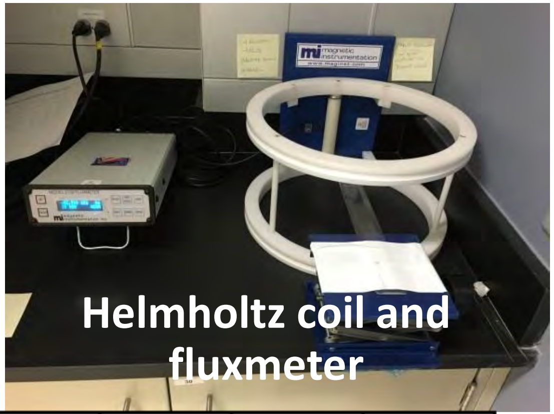
- BAAM magnet has density of 5.15 g/cm^3; intrinsic coercivity *Hci* = 704.2 kA/m; remanence *Br* = 0.58 T; energy product (*BH*)max = 57.7 kJ/m^3 (7.252 MGOe).
- *5% Porosity is present between layers*

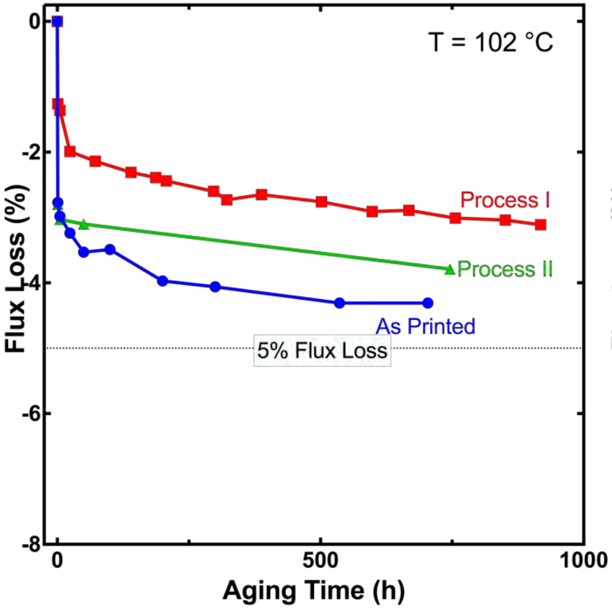


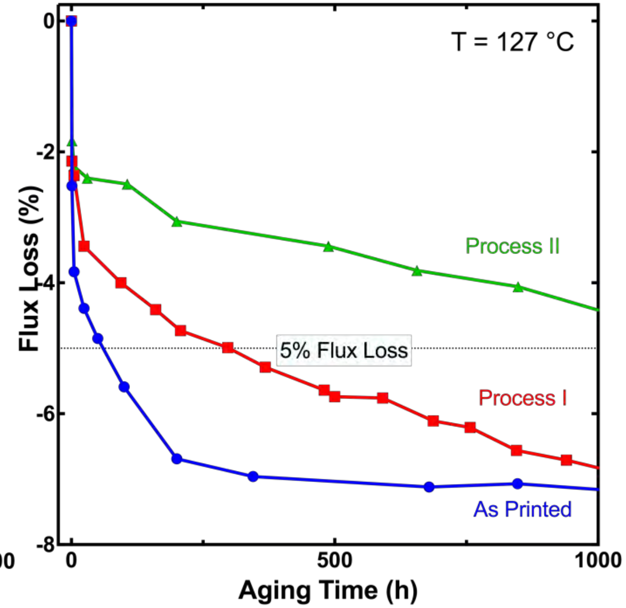
Additive manufacturing can now be applied to produce high energy product magnets

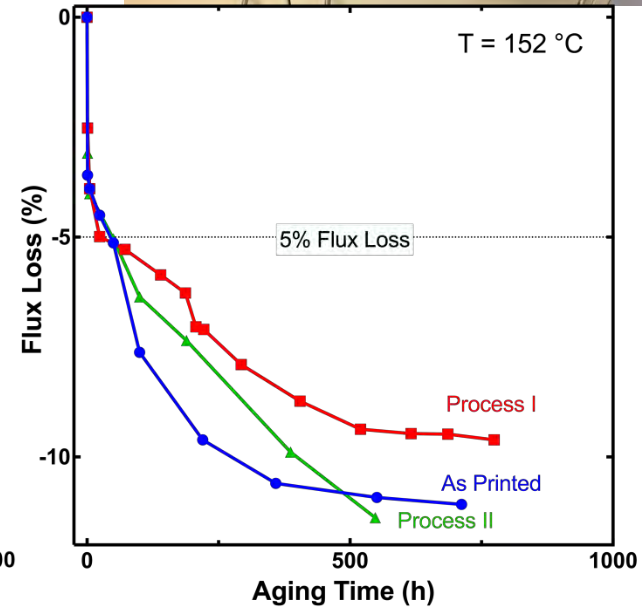
Li, L. *et al., Additive Manufacturing (2018)*

Thermal Stability and Flux Aging Loss of 70 vol% BAAM NdFeB Magnets – Flux Loss



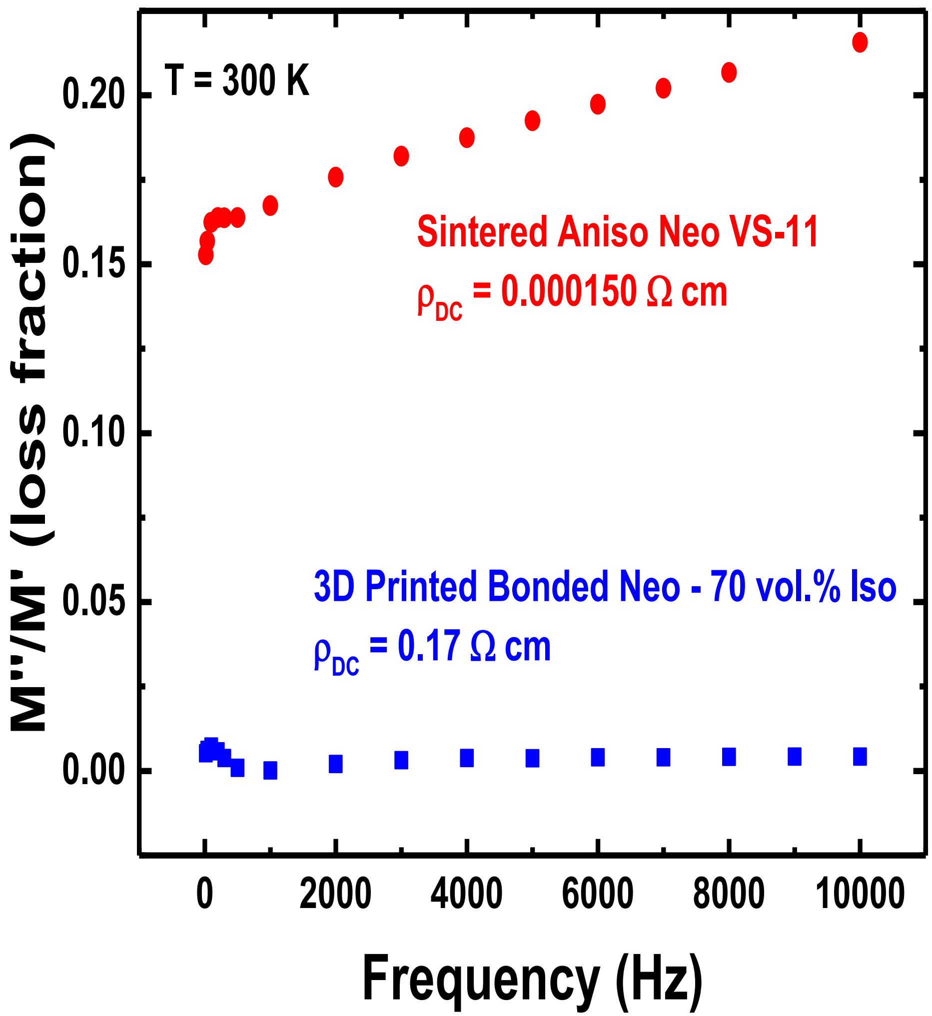






- Stable flux loss for 1000 hours at 77 and 102 °C
- Resin coatings improved the thermal stability and also increased the operation temperature to 127 °C
- Higher temperature stability is limited by the starting magnet composition

AM magnets outperformed Sintered NdFeB magnets with Reduced Eddy Current Loss and Improved High Resistivity



- Eddy current heating in large motors with permanent magnets can be significant
- Often eddy current heating is reduced by slicing the permanent magnets into smaller pieces
- Demonstrated the potential of using additively printed NdFeB magnets instead of standard magnets in motors where we can approximately achieve 1000 times less eddy current loss

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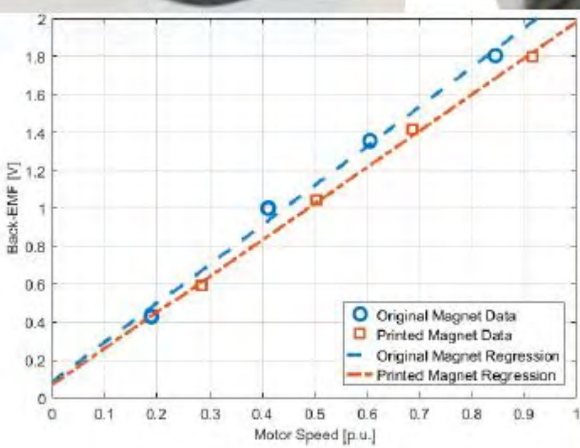
Successful Demonstration of AM Printed NdFeB Magnets in a DC Motor Configuration

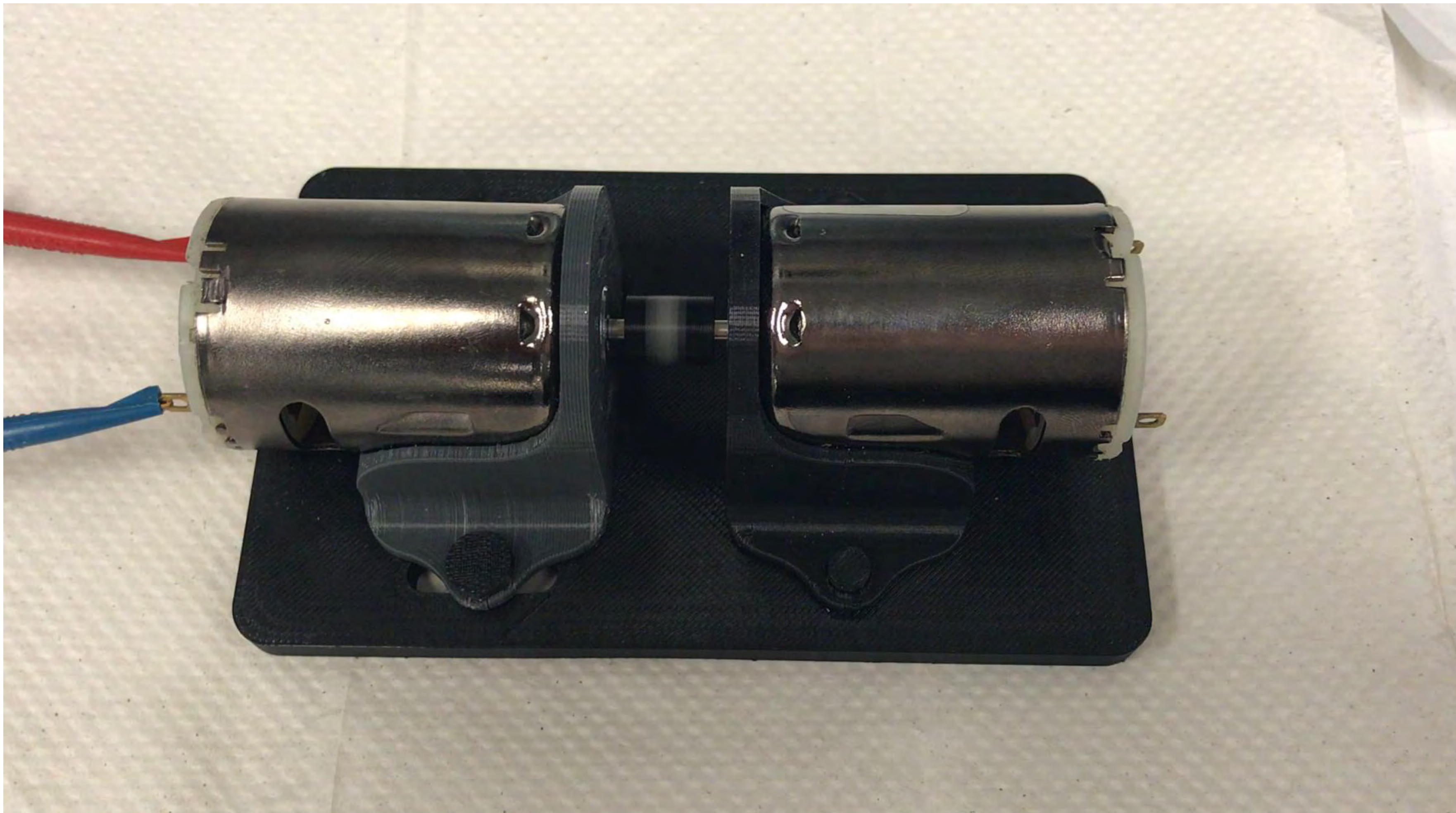
Printed Magnet Motors

- Replace sintered ferrite with printed NdFeB
- 3D printed small mounting plates for back-to-back testing

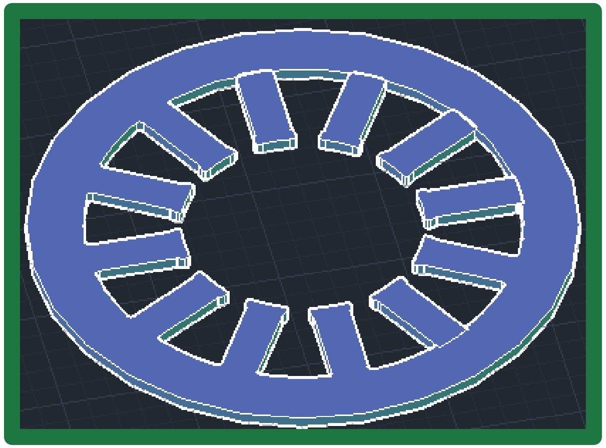


This work has demonstrated the potential of using additively printed NdFeB magnets instead of sintered ferrite magnets in motors

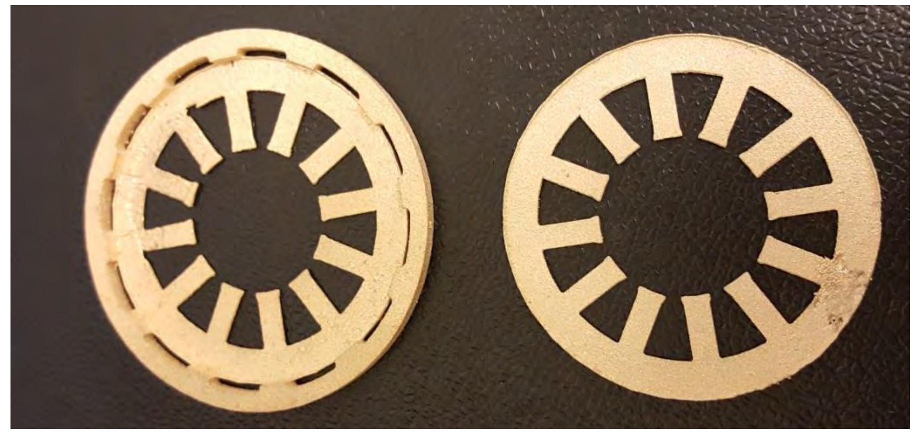
Applications – AM NdFeB Magnets in a DC Motor Configuration



Prototyping and Printing Stators and Rotors for Electric Motors and Induction Rotors



CAD Model



Binderjet Printed Stators
(Cu infiltrated Steel)

BAAM NdFeB Magnets

Moonshot: AM Motors (stators and rotors)

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OAK RIDGE National Laboratory

Summary

- Big Area Additive Manufacturing (BAAM) has been successfully used to fabricate near-net-shape isotropic NdFeB bonded magnets.
- Magnetic and mechanical characterizations demonstrate that the BAAM fabricated magnets can compete with or outperform the injection molded magnets.
- Additive manufacturing offers significant advantages such as cost effectiveness (no tooling required), fast speed (simple procedure), and capability of producing parts of unlimited in sizes and shapes.
- Effect of binder type, loading fraction of the magnetic powder, anisotropic particles, and processing temperature on the magnetic and mechanical properties of the printed bonded magnets will be investigated.

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

Challenges to Electrifying Defense Combat Systems

Bruce Brendle, Ph.D

Associate Director, Ground Vehicle Power & Mobility

US Army RDECOM Tank-Automotive Research Development & Engineering Center

23 AUG 2018

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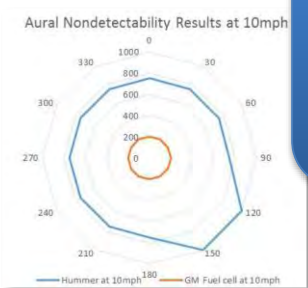
Operational Impact of Electrification



Reduced Signature

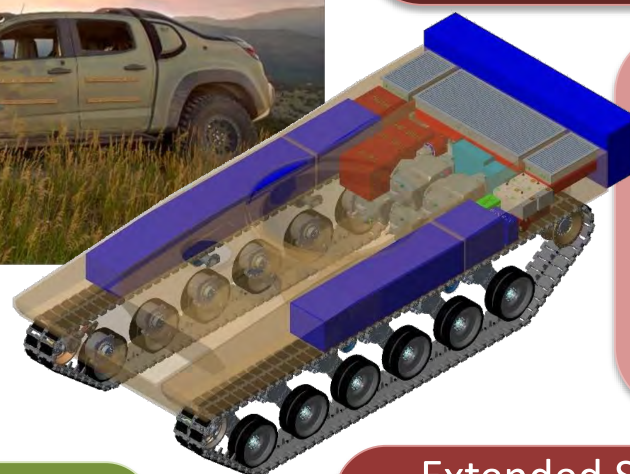
- 75%-90% Acoustic Improvement
- Thermal – Fuel Cells Run Cooler
- Remain undetected
- Place dismounts closer to objective undetected
- Enables new TTPs, ex: closer support by fire

Enables Improved Silent Off-Road Mobility

- Extended duration
- High Torque
- Greater Terrain Access
- Increases survivability

Enables Water Generation (Fuel Cell only)

- 800 kw = 53 gal water/hour
- Water at point of need
- Improves self-sufficiency



Increased Onboard and Exportable Power

- Export up to 100% of on-board power
- Enables Directed Energy
- Eliminates need for tow behind generators
- Decreases TOC footprint

Extended Duration without Resupply

- Approx 72hr increase in ABCT endurance @ 70% combat power
- 50%-60% increased duration

Extended Silent Watch (Fuel Cell)

- 15 kwh per kg of H2
- 4x duration compared to current fielded batteries
- Enables undetected reconnaissance

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Defense Electrification Challenges

Key Characteristics	Hybrid (Power Electronics)		All-Electric (Energy Storage)		Fuel Cell
	Power Density	Temperature Threshold	Capacity (300 mile range)	Charge Rate	Hydrogen Storage
Current / Army or Industry	3kW/L	85C Coolant	~0.15kW/L (best Li Ion)	100 kW	3.4MJ/L
Future Army Requirement	12kW/L	105C Coolant Engine coolant	0.60 kW/L	6 MW	13.6MJ/L
Improvement Required	4x *	24% *	4x **	60x ***	4x ****
Industry Gaps	High power density / high temperature power electronics a military unique requirement not being developed by industry.		High power / high energy / temperature a military unique requirement not being developed by industry.	Industry also desires fast charging. DOE leading effort to satisfy future military requirement.	Industry not investing in leap ahead military requirement.

* Silicon Carbide power electronics is the emerging capability.
** Beyond Lithium Ion energy storage is required.
*** 6 MW = ½ hour fill rate. Desired fill rate is ¼ hour = 12 MW.
**** Aluminum powder is most promising future technology.

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Implementing Emotions in Cognitive Robots

Lyle N. Long
Aerospace Engineering, Mathematics, and Computational Science
The Pennsylvania State University

Troy D. Kelley
U.S. Army Research Lab
Aberdeen, Maryland

Introduction

- Emotions and temperament help animals (including humans) survive
- Emotions are important memory triggers. Emotional events are remembered well
- Robots that vary their behavior based on their emotions should be more effective
- Although not addressed here, robots with emotions and temperament might be better at interacting with humans also

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Emotions vs. Temperament

ARL

- <u>Emotions</u> vary with time due to reward and punishment
- <u>Temperament</u> (personality) is essentially fixed, but can vary across individuals
- The model presented herein couples <u>emotions</u> and <u>temperament</u> together into a cognitive architecture on a mobile robot using the Symbolic and Sub-symbolic Robotics Intelligence Control System (SS-RICS)

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Emotions Used in Simulations

ARL

- ❑ Fear
- ❑ Anger
- ❑ Sadness
- ❑ Happiness
- ❑ Disgust
- ❑ Surprise

- All those shown in Plutchik color wheel
- Each can vary from 0 to 100
- Largest chosen (winner take all)

(could also model Trust, and others)

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Model Created for Emotions

ARL

$$Emotion(t)_i = w_{o_i} + \sum_{j=1}^{t} \gamma_i^{(t-j)} \left(w_{1_i} R_{ij}^{+} + w_{2_i} R_{ij}^{-} \right)$$

Eight emotions that vary with time

Fixed coefficients that define temperament

Rewards & Punishments

(Inspired by: Rutledge et al, PNAS 2014)

Note: There are similarities between cognitive models of memory and the above equation

Five main types of temperament in humans and other animals

- Often called the Big Five Temperaments (Digman, 1990):
  - Extrovert vs. Introvert
  - Neurotic vs. Rational
  - Conscientious vs. Careless
  - Agreeable vs. Disagreeable
  - Open vs. Reticent

Define a Temperament Matrix

Fixed array of constants to define robot's personality, from emotion equations

$$T_{ij} = \begin{array}{@{}c@{\quad}l@{}} \begin{bmatrix} w_{0_1} & w_{1_1} & w_{2_1} & \gamma_1 \\ w_{0_2} & w_{1_2} & w_{2_2} & \gamma_2 \\ w_{0_3} & w_{1_3} & w_{2_3} & \gamma_3 \\ w_{0_4} & w_{1_4} & w_{2_4} & \gamma_4 \\ w_{0_5} & w_{1_5} & w_{2_5} & \gamma_5 \\ w_{0_6} & w_{1_6} & w_{2_6} & \gamma_6 \end{bmatrix} & \begin{array}{l} \text{Fear} \\ \text{Anger} \\ \text{Sadness} \\ \text{Happiness} \\ \text{Disgust} \\ \text{Surprise} \end{array} \end{array}$$

Steady state value

Reward factor

Punishment factor

Decay rate

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Example Temperament Matrix

$$T_{ij} = \begin{array}{cl} \begin{bmatrix} 50 & 0.52 & 0.35 & 0.72 \\ 75 & 0.52 & 0.35 & 0.72 \\ 50 & 0.52 & 0.35 & 0.72 \\ 50 & 0.52 & 0.35 & 0.40 \\ 50 & 0.52 & 0.35 & 0.72 \\ 60 & 0.70 & 0.35 & 0.72 \end{bmatrix} & \begin{array}{l} \text{Fear} \\ \text{Anger} \\ \text{Sadness} \\ \text{Happiness} \\ \text{Disgust} \\ \text{Surprise} \end{array} \end{array}$$

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These values, so far, have been chosen to be near the values in Rutledge et al, PNAS 2014.

More work needs to be done in tuning tehse parameters.

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Cognitive Architecture Used

ARL

- Symbolic and Sub-symbolic Robotic Intelligence Control System (SS-RICS)
- Developed at US Army Research Lab, Aberdeen, MD (Troy Kelley, Eric Avery, Sean McGhee, and others)
- Inspired by ACT-R (Carnegie Mellon)
- Lots of libraries for navigation, mapping, visual processing, sensors, and motor control
- Laser range finder, mono camera, stereo camera, wheel encoders, sonar sensors, stereo microphones, stereo speakers, …
- Written mainly in C#

- Works with variety of robots (Mobile Robots Pioneer robots, the SRV-1 robot, the iRobot PackBot, and Clearpath's Husky A200)
- Easily moved to new ones

SS-RICS with Emotion & Temperament

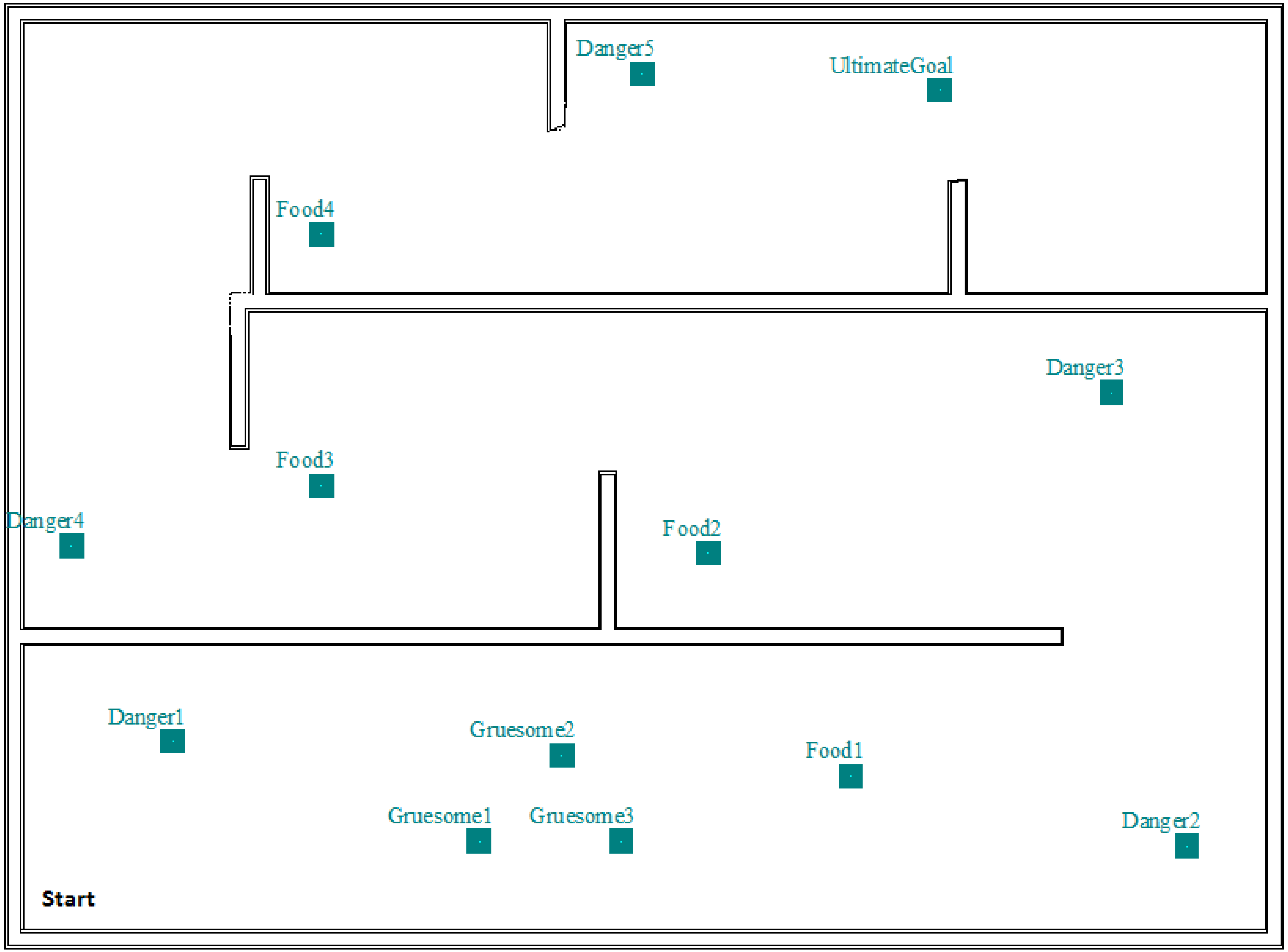
- The Emotion Engine is a sub-symbolic process (unconscious) within SS-RICS
- Written in C++
- Robot is given a temperament matrix to use (personality)
- As robot roams around SS-RICS sends rewards or punishment info to the emotion engine
- The emotion engine keeps track of these and uses the equations shown earlier to predict a numerical value of all emotions as functions of time
- Emotion engine sends current values of emotions (and info on largest one) back to SS-RICS
- Emotions are essentially state variables, so Productions can include info on emotions

Results

SS-RICS Simulation Results

- Simulator is given map of the building with objects that spur emotions distributed around map
- It roams around the building searching for one object
- Robot speaks when it is near the objects ("I see danger"), and these objects can change its emotion
- Robot also periodically states what emotion it is "feeling" (e.g. "I feel happy")
- **Depending on emotion it is feeling, its behavior is modified** via SS-RICS productions

Map Used for Tests



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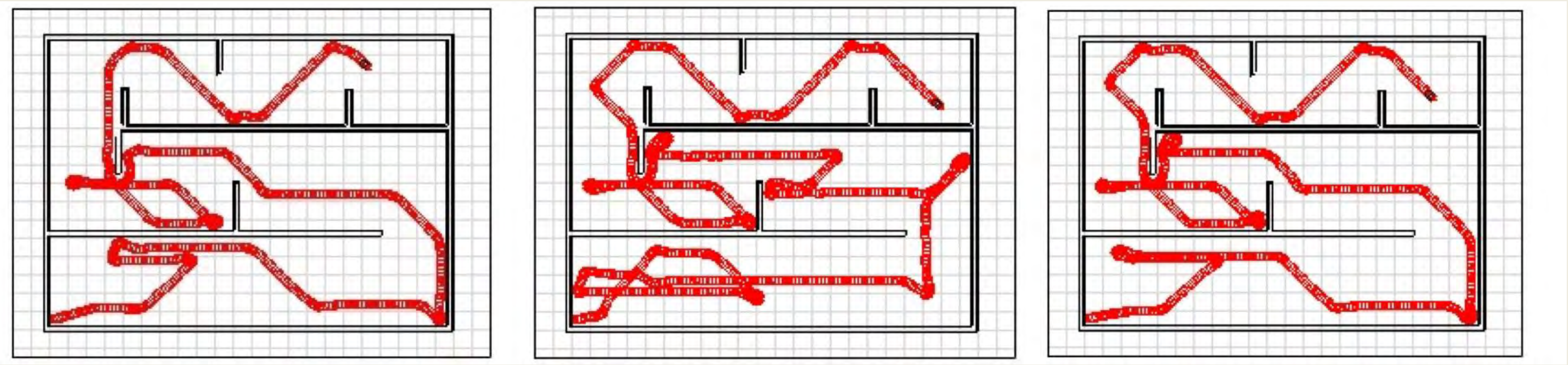
Routes Taken by Robots

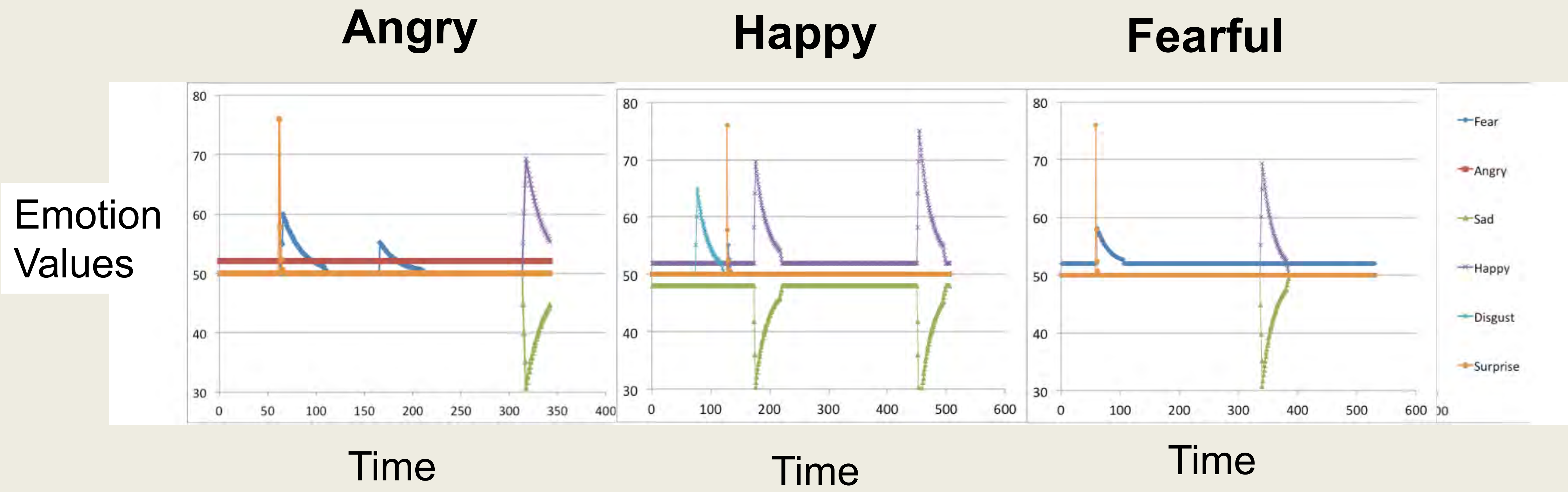
ARL



Angry Happy Fearful

Robots travel thru maze and experience items that effect their emotions. All robots go thru same maze and experience same items. Robots with different temperaments behave differently.

Emotion Time Histories



Robots travel thru maze and experience items that effect their emotions. Robots with different temperaments have different emotion time histories.

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Robot Test Cases

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Robot Results

ARL

- Ran the same tests as ran in simulator but on mobile robot (results were essentially the same qualitatively)
- Objects were stored in map
- Robot speaks when it sees these things ("I see danger")
- Robot also periodically states what emotion it is "feeling" (e.g. "I feel happy", "I'm afraid", "I'm very afraid")
- Depending on emotion it is feeling, its behavior is modified
- It roams around the building looking for a particular object while it builds a map of the building

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Conclusions

ARL

- Emotion and temperament model has been developed
- It has been incorporated into a cognitive mobile robot
- Will run more extensive tests in future
- Will also work to evaluate the emotion/temperament model and the temperament matrix
- It would also be interesting to couple memories and storage. Emotions can influence memories.
- More Details in:

Long L.N., "A Model for Temperament and Emotions on Robots. In: Chen J. (eds), Advances in Human Factors in Robots and Unmanned Systems. AHFE 2017. Advances in Intelligent Systems and Computing, vol 595. Springer, 2018.

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Thank You. Questions?

ARL

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SS-RICS: https://www.arl.army.mil/www/default.cfm?page=3236

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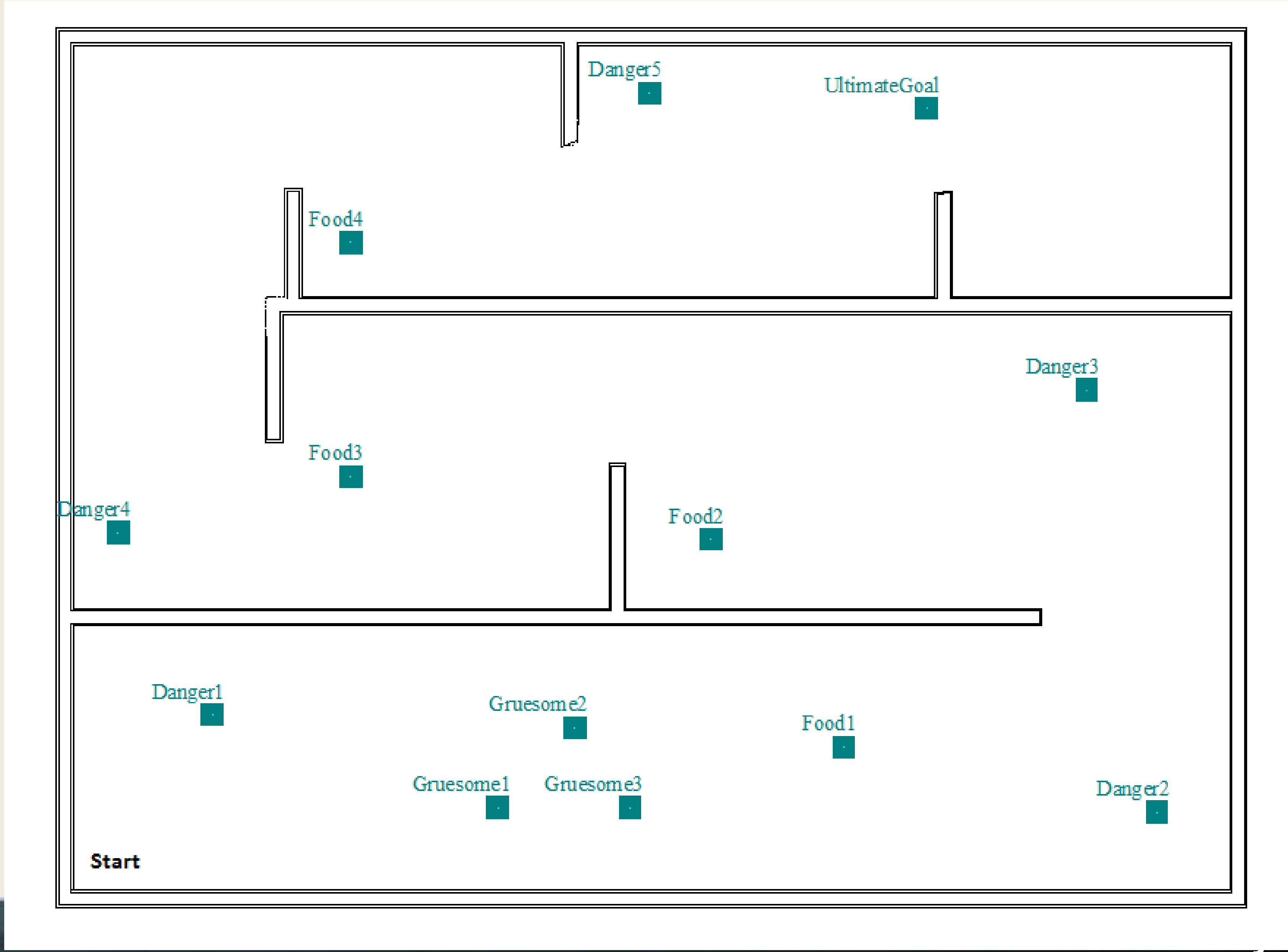
- **Depending on emotion it is feeling, its behavior is modified** via SS-RICS productions

Map Used for Tests



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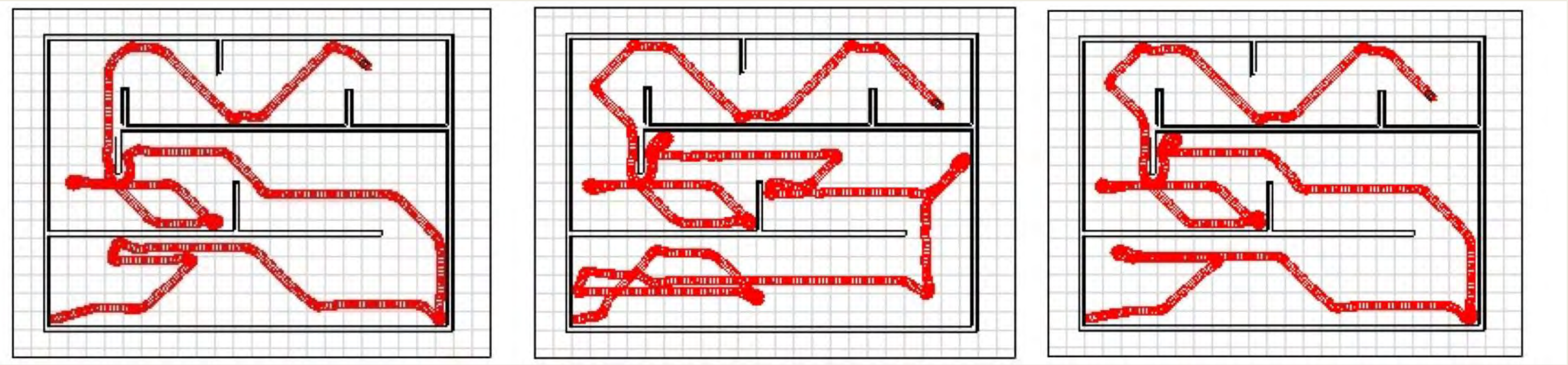
Routes Taken by Robots

ARL



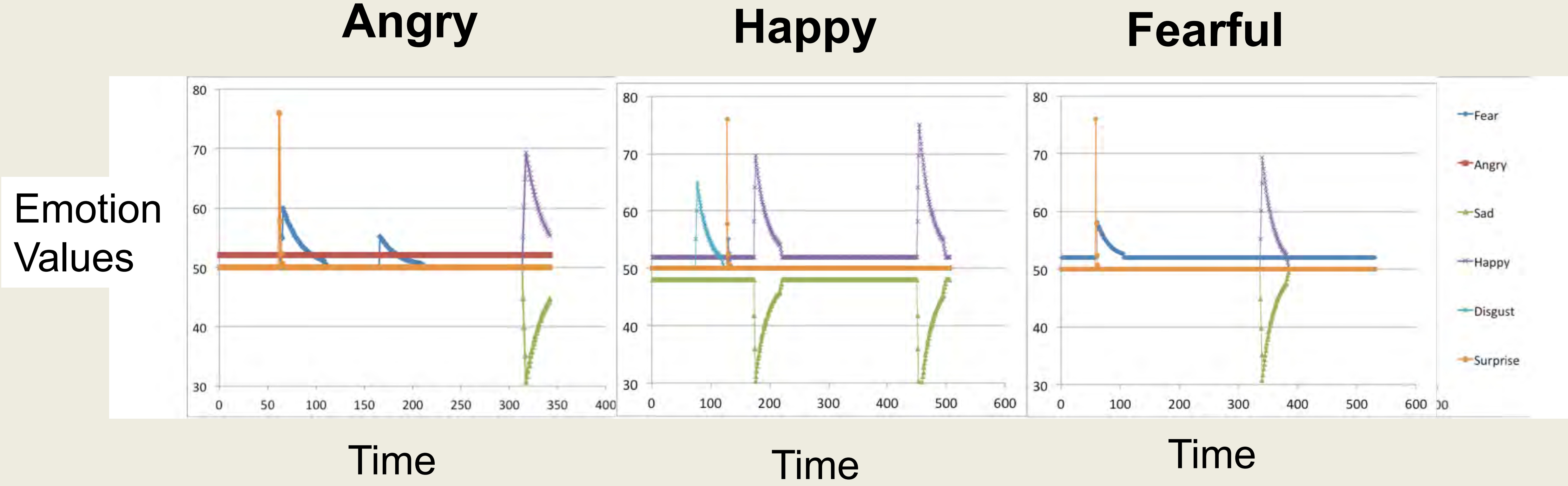
Angry

Happy

Fearful

Robots travel thru maze and experience items that effect their emotions. All robots go thru same maze and experience same items. Robots with different temperaments behave differently.

Emotion Time Histories



Robots travel thru maze and experience items that effect their emotions. Robots with different temperaments have different emotion time histories.

Robot Test Cases

Robot Results

- Ran the same tests as ran in simulator but on mobile robot (results were essentially the same qualitatively)
- Objects were stored in map
- Robot speaks when it sees these things ("I see danger")
- Robot also periodically states what emotion it is "feeling" (e.g. "I feel happy", "I'm afraid", "I'm very afraid")
- Depending on emotion it is feeling, its behavior is modified
- It roams around the building looking for a particular object while it builds a map of the building

Conclusions

- Emotion and temperament model has been developed
- It has been incorporated into a cognitive mobile robot
- Will run more extensive tests in future
- Will also work to evaluate the emotion/temperament model and the temperament matrix
- It would also be interesting to couple memories and storage. Emotions can influence memories.
- More Details in:

  Long L.N., "A Model for Temperament and Emotions on Robots. In: Chen J. (eds), Advances in Human Factors in Robots and Unmanned Systems. AHFE 2017. Advances in Intelligent Systems and Computing, vol 595. Springer, 2018.

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Thank You. Questions?

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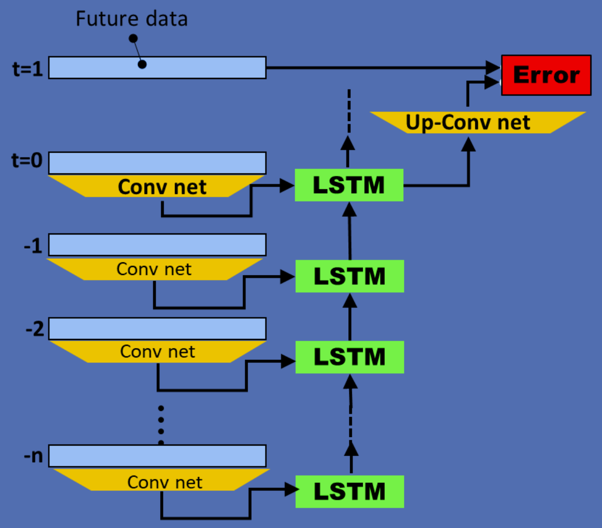
INTELLIGENT SYSTEMS

Tactical short range radar for personnel tracking with split-brain autoencoders

Mr. Rory McHenry, Engineer
Mr. Samuel Savage, Software Design Engineer Lead
Dr. Svetlana Foulke, Sr. Principal Systems Engineer
Alion / Weapon Systems and Sensors / Rapid Solutions Group

August 23, 2018



ALION

INTRODUCTION

We use AI to enhance the efficiency of radar detection, tracking, and classification in complex clutter environments.

As a stand-in for conventional signal processing, AI has potential benefits: it reduces computational overhead, enables detection in low SNR, and improves classification.

We explore representation learning using a convolutional architecture with actual unlabeled data, perform experiments to establish usefulness of new data mining techniques, and apply them to our radar target classification system.

- convolutional auto encoder with split-brain structure and L1 sparsity regularization
- convolutional recurrent neural network (to predict future Doppler spectrum)
- linear classifier (to classify tracks from learned representations)

Finding: the network learned unsupervised representations for a moving human target and for clutter, with an underlying ability to discriminate them.

Speculation: a single network can stand in for a large number of different processing steps to simplify a system.

APPLICATION

MOTIVATION

ARCHITECTURE

ALION

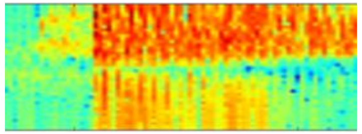
GOAL

- Our radar prototype demonstrated capability to track personnel moving behind three walls; however, the multi-path returns and other moving objects in the scene create complications.

- The user desires include
  - an improved classification capability
  - a capability to discriminate men from women and children

- Tremendous success of ML in object classification in images for disparate applications suggest a potential applicability of such AI tech for our classification problem.

- We can shape radar data as images with
  - dimensions: time, Doppler, range, azimuth, etc.
  - features depending on the chosen dimensions, relative location/orientation of the radar face to the structures, and on the choice of Doppler resolution.



- Our goal is to examine utility of ML for improved classification.

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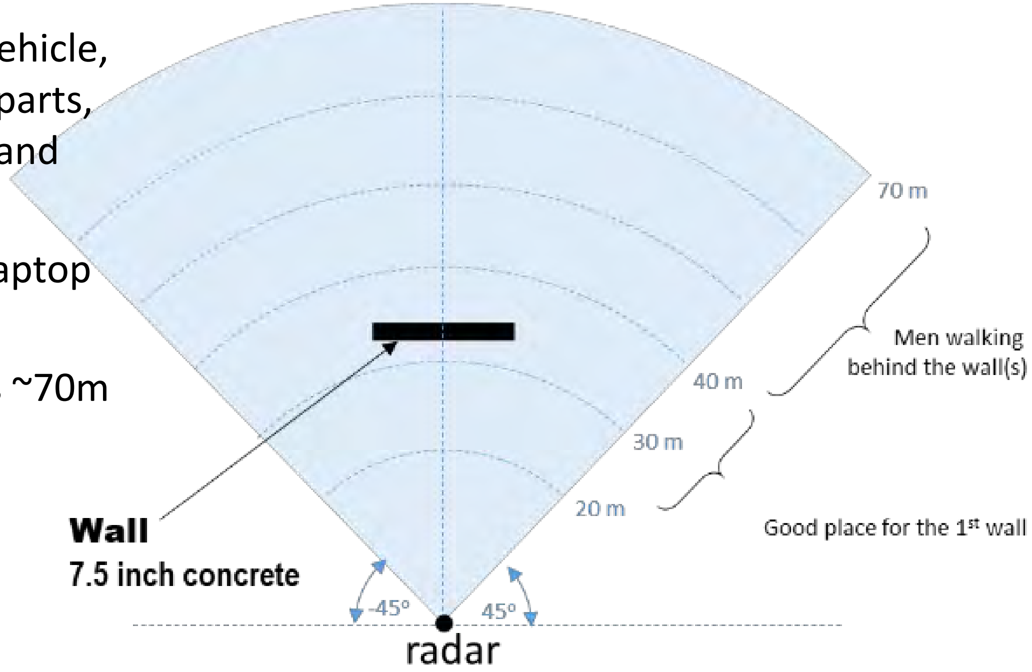
ALION RADAR Findr™

Alion Findr™ is a man-portable battery-powered multi-mode FMCW radar for foliage penetration, sense through the wall (STTW) surveillance of personnel, and tracking of autonomous vehicles both on the ground and in the air.

The STTW mode

- detects and tracks people moving within structures and behind obstructions
- provides operators the ability to identify the number of personnel and their location inside buildings from up to 150m standoff distance
- detects all moving objects (vehicle, stationary equipment with moving parts, aircraft, animals, birds, vegetation, and humans) and classifies them
- tracks are delivered real-time to a laptop with COP via 4G LTE wireless link
- a typical standoff detection range is ~70m with 1.5m range resolution



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NEED TRAINING-DATA FOR ML

Radar datacube: 3D FFT (range, Doppler, azimuth/beam) of the time domain data from the radar from various US DoD sponsored events, including

- 2018 Urban 5th Generation Marine (U5G) Advanced Naval Technology Exercise (ANTX), Camp Pendleton, CA
- US Army Special Ops Command (USASOC) 2018 Thunderstorm Technology Demonstration and Evaluation, Fayetteville, NC

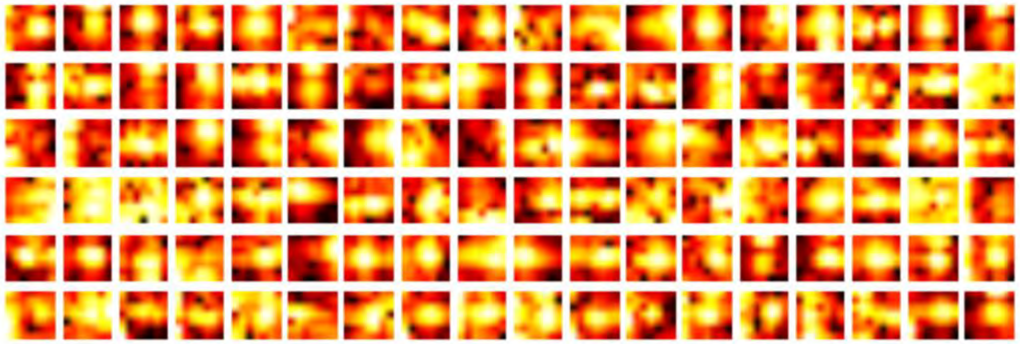
Plan

- create a semi-annotated dataset (from actual data)
- classify 'target' from 'no-targets' in small regions of range-Doppler preprocessed data fields (images)

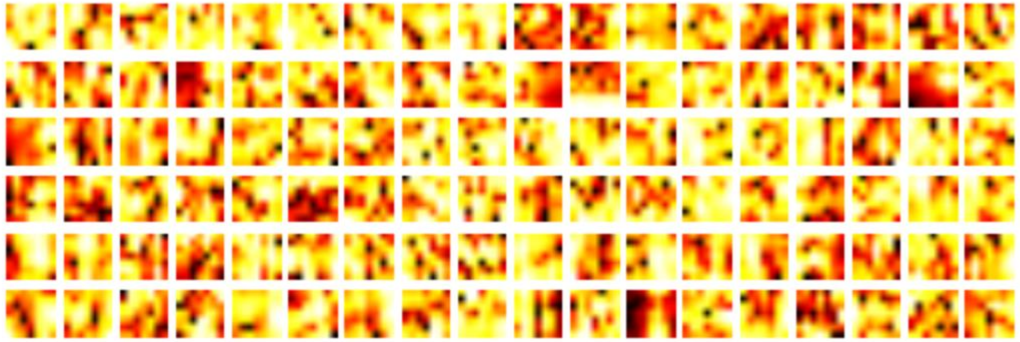
Dataset

- dataset shape (2368, 7, 7, 3)
- labels shape (2368, 2) using one-hot encoding
  - 1184 examples of each class, and each example is a complex 7x7x3 cube slice of the datacube
  - 'target' examples generated using detections from CFAR
  - 'no-targets' - random selections from the datacube

Target



No-target



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ML ARCHITECTURE USED

Supervised feed-forward convolutional network

- Trained a simple network to classify target/no-target
- Achieved 92% classification accuracy
- Computed on low-cost GeForce GTX 970, using tensorflow
- Training time depends on dataset and hyper parameters (ranging from hours to days)

Need to do better!

Convolutional split-brain

- Divide an unlabeled dataset into two: use one as labels and the other as input
- Let the neural network learn a representation without labeled data
- This technique works as a feature extraction on images with similar spatial structure to radar images

Long Short Term Memory (LSTM) with convolutional layers

- Run inference by processing each new row of data as it arrives (more efficient than the convolution-over-time approach, processing larger amount of history at each time step)
- Train to predict future frames from past frames. Use a variable amount of history for the prediction. The long term memory is promising for learning a running representation

Add time dimension

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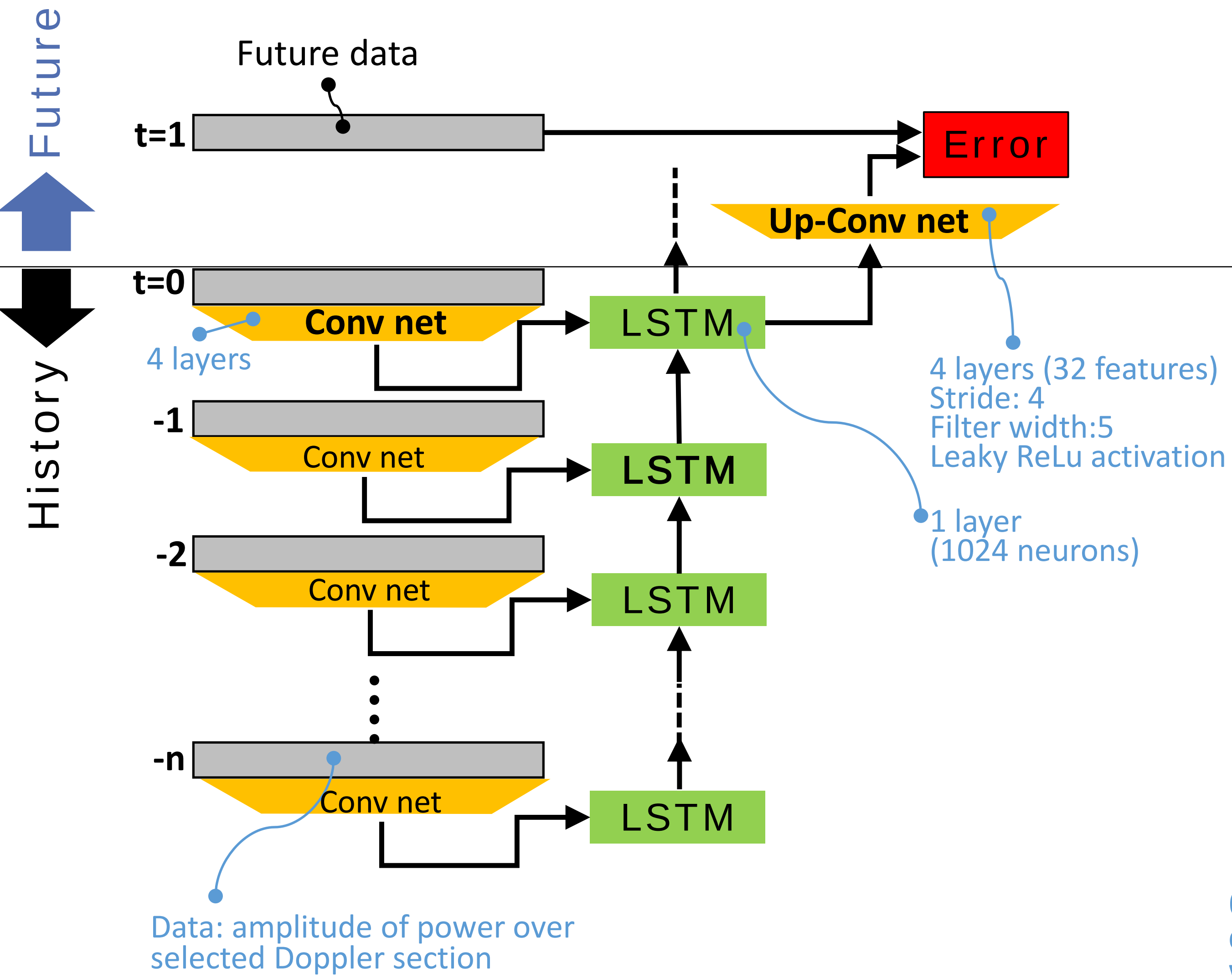
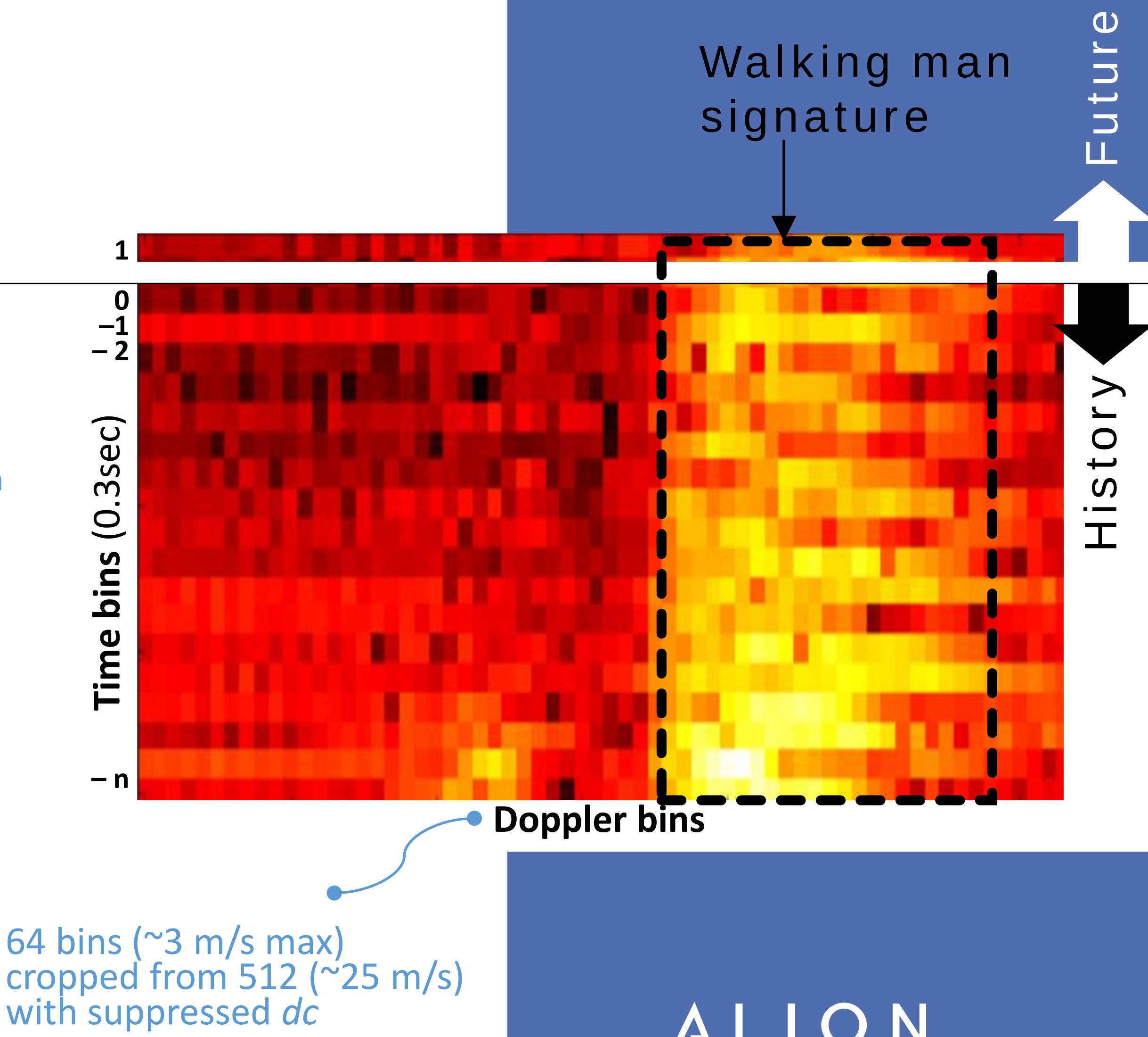
LSTM WITH CONVOLUTIONAL LAYER





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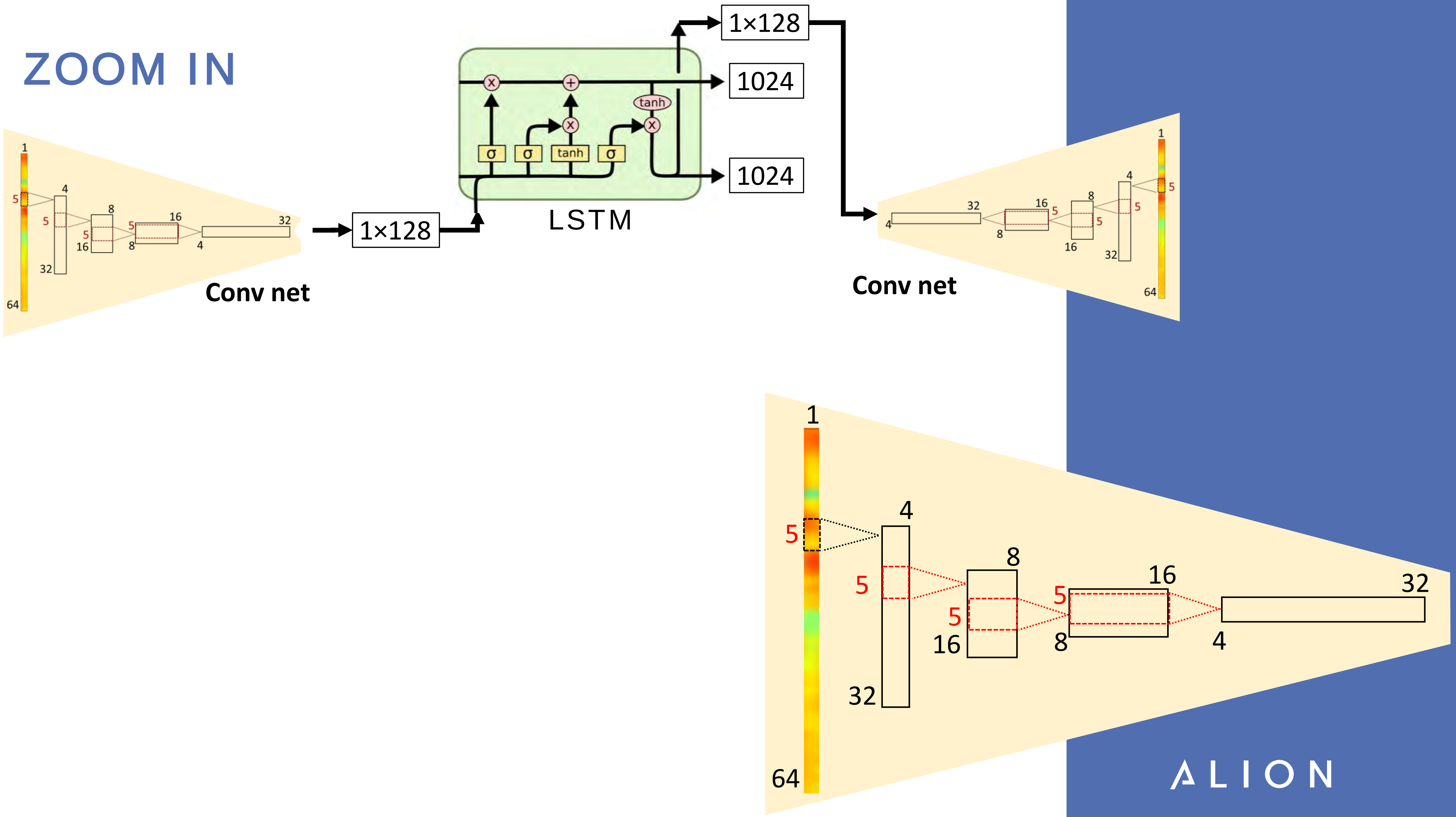
ZOOM IN



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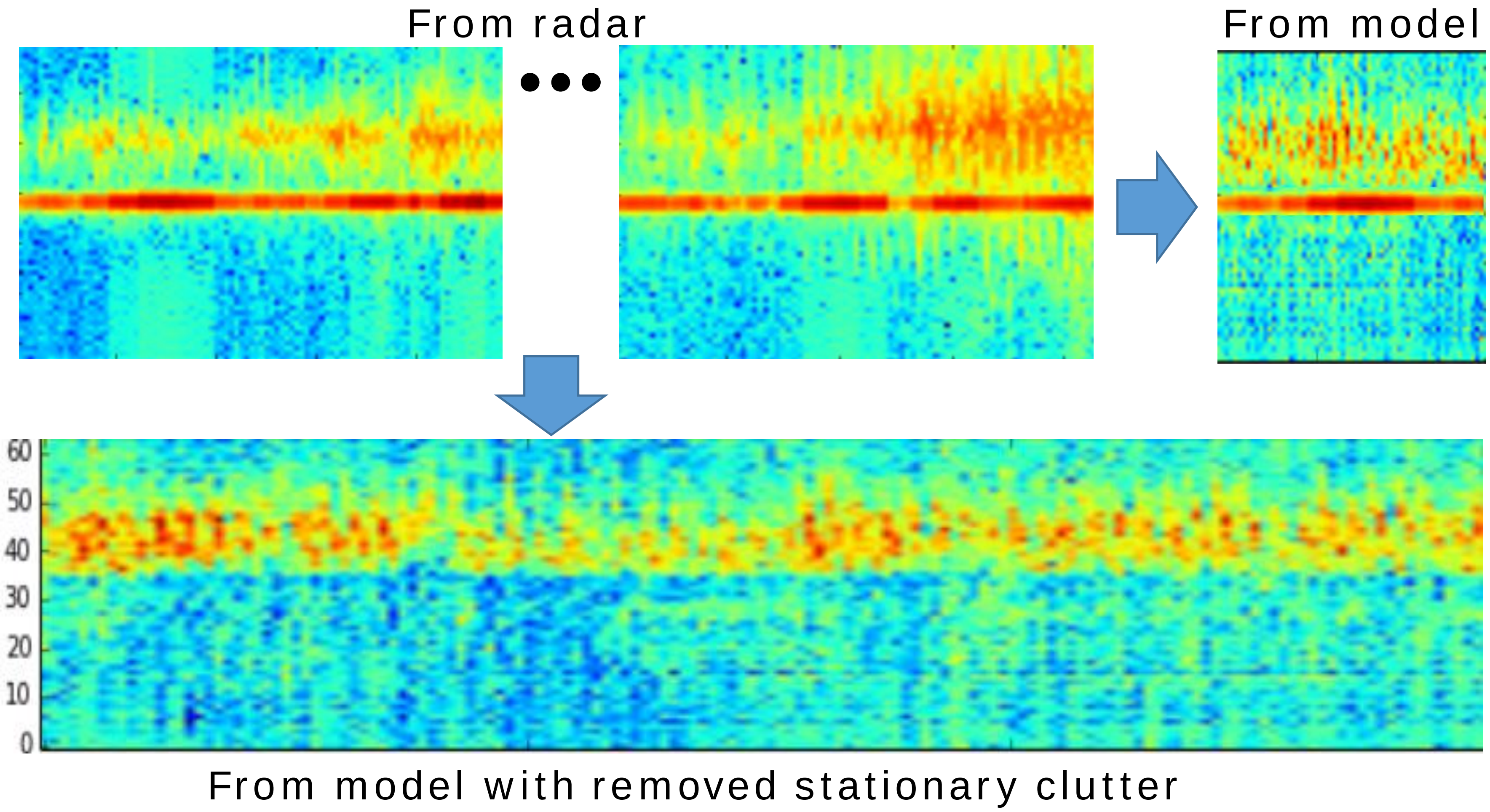
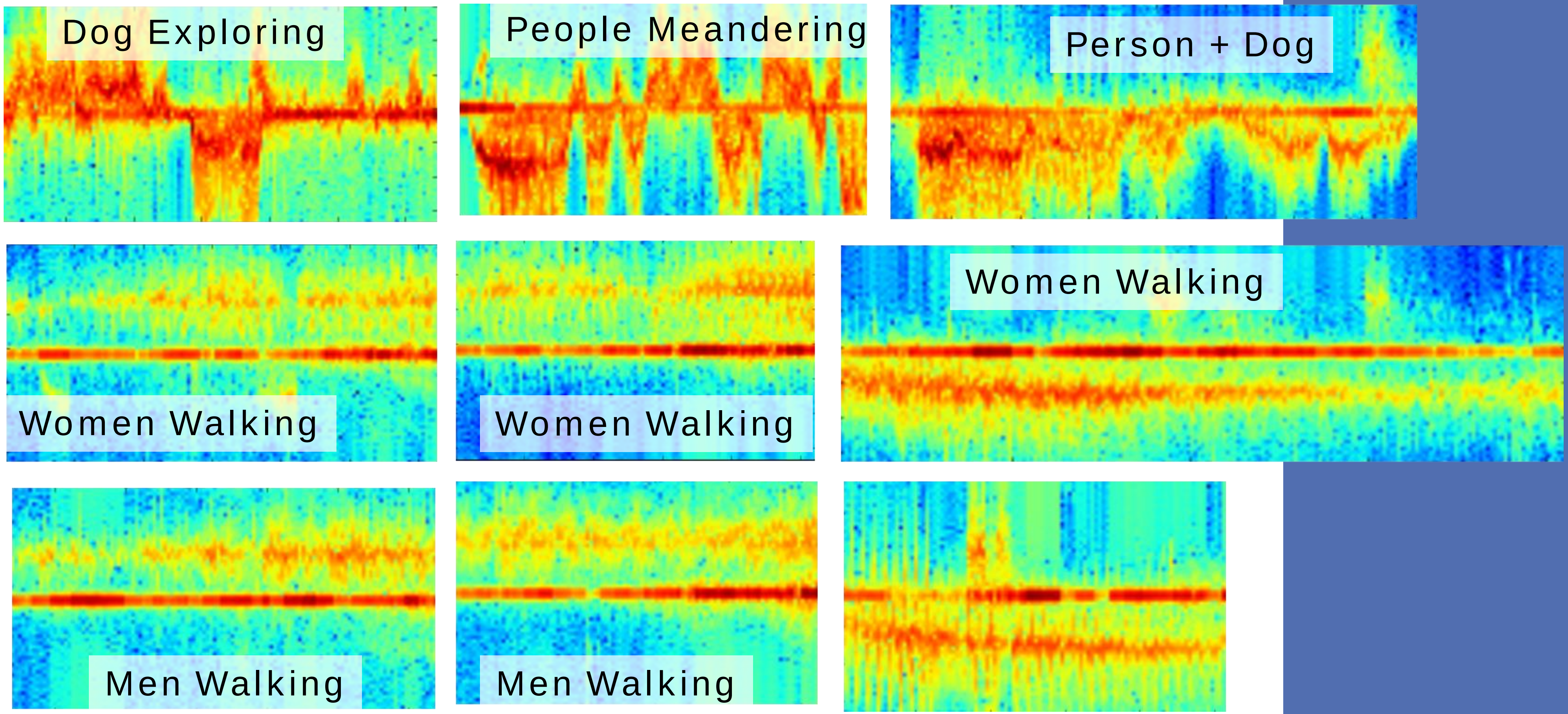
RESULTS

To verify that the LSTM has learned the structure of the training data, it’s predictions can be fed back into it’s input to create a possible Doppler history.
The arm swing Doppler patterns appearing in the generated Doppler history provide proof that the network has learned an internal representation of these patterns.



EXAMPLES OF POTENTIAL CLASSES



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CONCLUSIONS

- There is clear feature extraction however better performance is likely possible.
- We tested several architectures.
  - Can improve classification with traditional conv net by using more labeled data and deeper net architecture
  - Can pair a linear classifier with a net trained using unsupervised learning
- We found that shallow configuration (4 layers) can be adequate for feature extraction and feature representation on our radar data.
- We apply our representation as training data for a linear classifier and find that the classifier is effective on small amounts of labeled data. With additional data, we expect generalization to unseen targets.
- Speculations:
  - Using conv net over time appears to be equivalent to using LSTM with memory periodically erased
  - unlabeled data may be sufficient

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CLOSING

The practical applications of the research is in creating a learned representation of radar images, which includes detecting, tracking, and classifying the radar targets in complex environments.

The following are anticipated changes to existing practice resulting from this research:

- The change in design and signal processing philosophy: there is no longer a need to engineer algorithms based on known statistics to discriminate targets because the neural network organizes data from an existing dataset, finds a process that extracts features, and approximates a classification function. Subsequently, we can use the neural network as a substitute for the engineered algorithm.

The unique finding of this research is the confirmation that the network is capable of learning an unsupervised representation for a moving human target and for clutter with an underlying ability to discriminate them.

Thank You!

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